



*Office
International
de l'Eau*



**EVALUATION OF THE IMPACT OF FLOODS
AND ASSOCIATED PROTECTION POLICIES**

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Final Report

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Executive summary

1- General presentation of the project

Several floods in the 1990s have demonstrated that even where people felt secure relying on extensive protection works (e.g. in the Rhine and Meuse basins), floods could be severe and could cause massive damage. For example, Repairs cost billions of Euros in the Rhine basin in 1993 and 1995, around 350 M€ altogether in the French, Belgian and Dutch parts of the Meuse in 1995, around 800 M€ in the Vidourle (F) area in 2002. People discovered that vulnerability was very high.

Numerous types of measures are implemented throughout Europe to manage flood risk, combining prediction, prevention, protection, and information. Based on a literature survey, analysis was carried out in order to:

- Identify and quantify the damages caused by floods
- Evaluate and compare preventive and curative measures
- Characterise costs and benefits associated with policy options

Information and examples were selected from several basins but research focused on three basins:

- The Rhine, where ICPR decided to establish an action plan on floods following several flood events during the 1990s. Four strategic objectives were set [FLM09]: reduce damage risks, reduce flood levels downstream from the regulated Upper Rhine, increase flood awareness and improve the flood announcement system. On this basis, the action plan identifies several measures that should be taken by member states. The international context leads to specificities: e.g. the action plan set general objectives, and precise measures are elaborated at national scale. Then, despite the international dimension, several different approaches are implemented.
- The Loire, where in 1994 a multidisciplinary research team was set up for elaborating a flood strategy. Extensive research, in particular on economic aspects, led local actors to the conclusion that the initial approach, which mostly consisted of examining how to improve hydraulic control of the Loire, was not relevant [FLP11]. Indeed, it was considered that the reduction of hydraulic hazards would not ensure sufficient security for people and economic activities. On this basis, a strategy based on three pillars (prediction, prevention, protection) was proposed in 1999, following the comparison of several options and combinations of measures [FLP11], considering their respective efficiency in terms of reduction of damages and of exposed stakes. Decision makers have to date, however, not endorsed this proposal.
- The Vidourle, which is a French flash flood basin. The project considered whether some evidence of the specificity of the flash flood types could be found in terms of flood management policy. This basin is very small and there is no local institution that could be compared to ICPR or the Loire research team. Also, the action plan was elaborated under social pressure, following a very severe flood. Thus, there was no time for extensive preparatory studies. However, the flash flood character of the basin does not lead to any specificity in the action plan.

The situation in these three basins, including the contents of the action plans, is described in sections 1.1.3 (Rhine and Loire) and 1.1.4 (Vidourle).

2- Key findings of the project

2.1- Regarding the use of scenarios to design flood management policies

The use of scenarios in defining flood risk management strategies is in fact not very common as can be judged from literature, and where they are employed, they are normally used to determine the impact of a predefined set of measures in comparison to a “do-nothing-option”. To this regard, it is important to

indicate that the term “scenario” is used differently by different authors. In most cases observed scenarios are described in terms of the return period of a flood, but this does not constitute a scenario as it is understood in this study.

Another finding is that the actual measures that would need to be considered in a scenario are highly site-specific and it is therefore not possible to construct meaningful scenarios that could be applied on a European level; at best, a general typology of approaches can be described that could then be developed into concrete scenarios at the river basin scale. The approach followed in this study was therefore to identify and survey the scenarios that have been used in the river basins at the centre of this study (namely the Rhine and Loire¹), and where possible to then derive conclusions for the European policy process. Detailed analysis is proposed in section 5.

For the **Rhine**, elaborated scenarios do not exist on the basin level. For the main course of the river, the damage atlas compiled by the Rhine Commission provides a few building blocks for scenarios but does not present proper scenarios [FLD03]. As for the local action plans that have been drawn up for some tributaries of the Rhine, these make use of scenario analysis to a different degree. Academic research presents in fact the only example of proper scenario-based analysis [FLE23]: a combination of cost-benefit analysis and multi-criteria-analysis is used to compare the effects of two scenarios with a “do-nothing” baseline scenario.

For the **Loire**, five scenarios have been developed in order to assess the potential damage and the impact of measures [FLP11]. Four action scenarios that consisted of different combinations of measures complemented a baseline scenario, made up of a set of basic measures that were to be implemented in any case. They were then evaluated under three different hypothesis (related to the probability of dyke failures and groundwater upflow) and for four different return periods (HQ₅₀ to HQ₅₀₀). In the end, the scenario selected as the recommended course of action combined the highest costs and the highest benefit (8 – 17 million Euro p.a.). However, this work presented in 1999 remains as a proposal as decision-makers have not endorsed it.

2.2- Regarding the use of economic assessment methods

The use of economic assessment methods, especially cost-benefit analysis (CBA) in order to select, design and implement flood management measures is rather traditional in some countries, such as the UK, the Netherlands and Germany. In principle, the methodology for CBAs can be considered as sufficiently developed and established for providing useful inputs into policy formulation.

Yet, some problems limit the application of CBA: e.g. availability of data, insensitivity of CBAs towards certain types of impacts, difficulty of expressing certain impacts in monetary terms, limited openness to public participation and stakeholder involvement. Furthermore, in practice, CBA is *de facto* mostly used for the assessment of individual, well-specified flood management measures or the combination of measures. On higher aggregation levels, CBA is not normally applied, as uncertainty of the results increases substantially. These factors limit the scope where CBA can be usefully applied, but not to the same extent in all countries. E.g. as intensive use of CBA is made in the UK, efforts are made in order to reduce these intrinsic limits of CBA (provision of a detailed national method, establishment of comprehensive tables of reference costs of damages, etc.).

Therefore, in some of the countries, assessment practice has gone beyond a pure CBA, complementing the analysis with qualitative elements or using a Multi-Criteria Analysis instead, e.g. in France or in the Netherlands [FLD26]. Though they cannot eradicate all of the uncertainties involved in a CBA and may introduce new uncertainties, MCAs do take up the most criticised aspects of CBAs. A particular strength of MCA is that it allows for a transparent decision making process, where assumptions need to be explained to or discussed with stakeholders. On the other hand, typical setbacks are that MCAs are often difficult to understand and use for the general public.

In practice, decisions at the strategic level are often the result of political bargaining, e.g. by specifying a certain protection level that needs to be guaranteed at any cost. Although such decisions may be informed by economic considerations, the protection level itself is not the result of an economic trade-off.

¹ In the case of the Vidourle, taken as an example of flash flood basin, no evidence was found to demonstrate the use of some sort of scenario (whatever the sense given to this term) in order to establish the local flood management action plan.

3- Selected outcomes from literature survey

3.1- Regarding the damages caused by floods and their estimates

Several types of damages exist: residential sector, economic activities, agriculture, public buildings and networks, environment, human life and health. Subcategories can be identified for each of these main damage areas. Direct and indirect damages are one specific example. Classification of direct or indirect damages depending on whether damages are caused by the flood itself (e.g. destruction of machines) or are a consequence of the initial damage (e.g. loss due to the disruption of activity). Several figures and examples on damages are provided in Section 3 of the report. Due to this wide diversity, situations are very heterogeneous in practice:

- Most attention is paid to most quantifiable damages. In other words, damages to residential sector are much better documented than damages to the environment. High levels of knowledge are not linked to the respective importance of each type of damage. E.g. human health and well-being (stress, anxiety...) are often considered as (one of) the most important damages for flood victims but these are very difficult to capture with traditional assessment methods.
- The share of the different types of damages varies considerably from one case to the next and no general trend can be identified. E.g. in a number of recent floods that occurred in France, damage to the residential sector accounted for 18% to 42% of all damages, damages to agriculture sector accounted for only 1% to 29% (see section 3.1.3).
- Transferability of data from one case to another (and even from one country to another) is unclear according to literature, as cultural factors may be very strong. E.g. the type of housing and the level of equipment, which are keys to determine the vulnerability of an area, vary significantly among different countries.

This high diversity of situations makes it very difficult to establish reference data. The most refined example on this point is the English one: regularly updated national tables have been set and fed into for years [FLD12].

3.2- Regarding the measures implemented and the associated benefits

Several types of measures may be implemented as part of flood risk management policies. In many basins, action plans have been established in order to ensure a coherent approach to this issue and to co-ordinate actions of different actors. Yet, it is important to notice that action plans are generally only the most visible part of the flood policy: actions may be taken apart from the plan, and several sectoral policies may also contribute to a more efficient flood policy (e.g. agriculture policy). Another key aspect to keep in mind when considering measures and action plans is the working scale, as this may lead to completely different statements.

Based on the action plans examined for this project, some general trends can be identified:

- The link between measures and expected benefits is often unclear in the action plans: in most cases, either no benefit is announced in the plan or it is only indicated in very general terms (e.g. reduction of damages). One major reason seems to be that expected benefits should come from the combination of sets of measures rather than from individual ones.
- Information measures have proved to be efficient in several cases (Meuse, Bretagne, Saône...) and inexpensive as well. Very encouraging figures are available: e.g. a four hour delay allows a 40 to 50% reduction of damages in housing [FLD14]; the total damage may be reduced by 20 to 50% by removing furniture and equipment or by elevation [FLD12]. Public authorities are put under high pressure to this regard, as people are very demanding: alert has to be detailed, to provide practical information, to come at the correct time (not too early and not too late).
- Prevention measures show positive impact although it is often difficult to quantify precisely. It seems that implementation is difficult as the adaptation of uses of flood prone areas requires coping with existing activities (e.g. changes on buildings, relocation of activities...). It is then necessary to adapt measures and actions to the local context, to organise local co-operation, etc. Therefore, this takes time and is very demanding in terms of human involvement. Besides, administrative procedure may slow this process.

- Protection measures in action plans considered are widely based on the construction of local works (reservoirs) rather than on large projects. As people begin to understand that full protection against flood is not possible, the “living with floods” approach develops. Public authorities then tend to reconsider traditional protection measures mainly based on the reduction of hydraulic hazard in order to ensure security to people and economic activities and to pay more attention to the reduction of the vulnerability. Evidence of such evolution is found in most basins considered.
- Emergency measures, which may have significant impact on the level of damages, are rarely included in flood action plans, but rather in civil protection policies. Yet, closer co-ordination between both sectors may increase the potential of damage reduction by 50 to 75% in the industrial sector [FLM12], as some specific measures may efficiently supplement traditional emergency measures (e.g. evacuation).

4- Recommendations

The following recommendations for the integration of economic aspects in a flood protection strategy can be made:

- Common problems and issues and common ways of dealing with them can be identified but specific solutions are required for each specific case. Thus, the potential for exchange and transfer of experiences will be much greater on the level of procedural questions. Despite the statement on the specificity of action plans, the category of information measures recommends itself as inexpensive yet effective throughout the basins considered.
- Having a basin-wide action plan specifying objectives and possible measures at the local level is beneficial both because it lays the foundation for an efficient flood management strategy and because it creates the conditions for a participatory process.
- As the establishment of action plans on floods is in line with the WFD objectives and methods, a possible role for the EU could be to ensure the use of coherent methodologies. This could be made through the directive on flood risk management currently under preparation, e.g. by specifying the role, position and weight of economic appraisal in the decision making process. Doing so, it should be kept in mind that political culture and tradition in a country, as well as the availability of sufficient skills and knowledge are essential.
- In order to cope with lack of data to carry out economic assessment, transfer of actual estimates on costs and damages can be considered. However, it should be noted that it makes sense for some types of costs and damages, and under certain conditions only: for example, the calculations of damage potential in the Rhine damage atlas [FLD03] are partly based on German damage figures that have been transferred to the Netherlands and to France. this was made possible as in this case, only rough estimates were required. Such a transfer of values is also relevant in the case of transferring valuation of environmental benefits. However, it needs to be ensured that the two sites between which values are transferred are sufficiently similar. Besides, the scale of the transfer of data is also an important issue: it is doubtful that transferability of data from one country to another can be a systematic solution to bridge the knowledge gap. It is indeed suggested [FLM35] that this should be considered very cautiously in the case of damage to the residential sector, as housing and equipment are very closely linked to national (maybe even local) context and criteria (e.g. wealthness, type of housing, type and level of equipment...). Such restrictions may not apply for damages to economic activities however, as the characters of the damages are more linked to the type of activity. Further research would be relevant on this aspect.
- When considering the potential role to be played by economic appraisal tools, it should also be remembered that they are primarily concerned with the economic efficiency of the result obtained and that they are not initially designed to consider criteria such as impacts on equity / distribution of wealth, preservation of historical and natural values, avoidance of personal stress, or the degree of solidarity in flood risk management. Such methods should then be adapted to the local context and to the aim of each procedure in order to ensure adequate combination of CBAs and MCAs in particular. This does not challenge the relevance of economic assessment

methods in general, but rather addresses the conditions of their use and identifies the context where they are most valuable.

- The widespread neglect of intangible benefits and of environmentally beneficial side-effects in many CBAs, or the failure to include non-structural measures altogether are causes of concern. However, there is evidence that the inclusion or exclusion of such effects can tilt the balance of judgement on the economic desirability of a project.
- Conditions in which decisions on flood risk management are made are also a key element: in many basins (Rhine, Vidourle, Moselle), it appears that the decisions are very much driven by events. In the aftermath of major floods, far reaching decisions are often made and implemented swiftly, apparently irrespective of cost-benefit considerations. On the other hand, the case of the Loire suggests that in the absence of flood and in the associated context of limited awareness, it seems to be more difficult to arrive at decisions, let alone to implement them.

Despite their limitations, economic appraisal tools are able to make a significant positive contribution to flood management, as they force decision makers to consider the costs and benefits of their actions and to aim for an efficient allocation of resources. One of their most criticised aspects, the need to monetise all impacts, is also one of their main strengths, as it allows the comparison of different measures beyond the local scale. Provided that consistent methodologies are used, it is possible to compare the benefit-cost ratio of measures in upstream and downstream areas, in order to define an approach that is efficient at the river basin scale. In this respect, economic appraisal of flood management can play an important role for the integration of flood management strategies, both within and between countries.

Part 1- Setting the scene

Over the years, floods are becoming a more and more important issue. As severe events regularly occur, damages increase reaching huge amounts of money. From a human point of view, between 2000 and 2004, floods have killed 185 people in EU15 and affected half a million according to the Emergency Disasters Data Base which identifies 63 flood events (see table).

Consequences of floods in EU15 between 2000 and 2004

Country	Number of floods	Human casualties			Estimated financial damages (x1000 US\$)
		Deads	Injured	Affected	
Austria	1	7	0	60 000	2 046 407
Belgium	5	2	0	2 400	0
France	16	42	13	49 661	2 832 350
Germany	2	34	128	331 000	10 460 447
Greece	11	12	0	8 490	656 218
Ireland	1	0	0	300	0
Italy	12	59	22	57 550	2 506 960
Portugal	3	7	0	296	0
Spain	3	21	0	1 250	14 285
United Kingdom	9	1	8	2 460	6 918 150
Total	63	185	171	513 407	25 434 817

Source: "EM-DAT: The OFDA/CRED International Disaster Database - www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium"

As countries develop, level of (potential) damages increases parallel to wealth: should level of exposure remain the same, the value of both exposed private properties (either residential or not) and public equipment and networks grows. Recent flood events in the 1990's have demonstrated that even where people felt secure relying on extensive protection works (e.g. in the Rhine and Meuse basins), damages were huge and water was not stopped. People discovered that vulnerability was very high.

Yet, several types of measures are implemented all over Europe, combining prediction, prevention, protection, and information in many different ways.

What are these measures? How are they designed? What benefits do they generate (or are they expected to generate)? ... These are some questions the project addresses.

1.1- Introduction

1.1.1- Aim of the project

The general aim of the project is threefold:

- **to identify and quantify the damages caused by floods**

This refers both to the types of damages and to their appraisal in monetary terms. A typology of damages will be set in order to organise information homogeneously.

- **to evaluate and compare preventive and curative measures.**

A typology of measures will be defined and information collected will be organised and classified on this basis, what will allow comparisons.

Yet, it is not intended to compare flood risk management policy defined in one basin *vs* the other, nor to assessing/judging the quality and relevance of these policies. The aim of the comparison is

rather to identify common trends and differences and to raise statements and questions regarding different types of measures (specificities, etc.).

- **to characterise costs and benefits associated to policy options.**

Based on the analysis of different cases, it is intended to prepare tables on costs and benefits as this may bring evidence of specific characteristics of given policy options. E.g. more relevant in a given context. E.g. likely to generate a specific type of benefits. Etc.

Focus will be put on economic aspects of flood risk management and on the cost-benefit balance of given measures, considering different situations (plain floods, flash floods) and different intensities of floods, and parameters such as the scale to implement given measures or the type of area concerned (settlements, industrial, rural)

In concrete terms, the key output of the project will be *an inventory* of:

- what is done in the field of flood risk management in the Loire and Rhine basins in particular (examples will also be picked in other basins);
- how it is done: methodology, approaches, level of achievement...

Besides, it is important to bear in mind that:

- the project takes place in a specific context regarding flood policies at European level (see 1.3 below): the Commission is working on a proposal for a directive, and the project is intended to contribute to the impact assessment;
- the project is based on a bibliographic research and on analysis of literature: action plans, policy papers, articles, research projects, official documents, etc.

1.1.2- Scope of the study

From a geographic point of view, focus was put on two large European basins: the Rhine and the Loire. As will be described below, the situation regarding flood policies is quite different in these basins. Yet both have experienced severe floods in the past (more or less recently) and initiatives have been taken for a long time in this sector.

Besides these two basins, we have collected data on several other places where action plans have been established and/or where recent events caused significant damages. This is likely to enrich the sources of information and to provide a wider basis for analysis, then allowing more representative comments. Indeed, though basins are all very unique and all experience unique floods, it is possible to see that approaches are not necessarily that unique.

From a physical point of view, our prior concern was for fluvial floods. Though in some parts in both the Rhine and the Loire basins flash floods may occur, it appears clearly in literature that in both basins attention is paid to areas where most stakes are exposed i.e. middle and lower stretches of the basins rather than upper or high ones. In the Loire for instance, 80% of stakes exposed to the maximum flood (as in 1856) are located in the middle Loire, concentrated in 9 spots only [FLD06]².

However, we have also paid some attention to a basin subject to flash floods, in order to look at potential specificities: it is indeed interesting to determine whether the specific characters of flash floods (short duration, power of the flow...) lead to specific approaches in terms of flood policies. Documents have been collected from several such basins, in particular post event surveys (see bibliography in annexes). Most attention has been paid to the Vidourle basin, located in the South of France.

² For practical reasons, as we have collected lots of documents, an express codification was used. Documents have been classified into 4 categories, each with a specific code, depending on the aspect they address: Floods Policies (FLP), Measures (FLM), Damages (FLD) and Economics (FLE). Then, in each category, a number is given to each document. Full bibliography is provided in annex.

As indicated in the description of the aim of the project, focus was put on economic aspects of flood policies i.e.:

- the costs of the measures implemented, the costs of the associated avoided damages as well as the costs of occurred damages;
- the socio-economic assessment methods used in all these basins when designing and/or implementing policies. This includes the identification of the methods themselves, but also the conditions under which there are used, their advantages and disadvantages, the discussion regarding their relevance...

This analysis was based on a literature survey. Several types of documents have been collected: action plans, post event surveys, official reports, articles, policy papers... Although our main concern was for the Rhine and the Loire basins, we collected information regarding other basins in order to widen the scope and relevance of analysis.

We have carried out an extensive collection of documents, including several contacts and interviews with experts from France, Germany, the Netherlands, Switzerland and UK. Yet, this type of research is submitted to practical constraint, basically availability of information and co-operation of contacted persons. Besides, time shortage (the all project lasted for 3 months only) imposed us to work on rapidly available documents only. Another consequence of the short duration of the project is that we worked mainly at large level i.e. at basin level. Yet, on some aspects, local data could be useful e.g. to consider individual measures and associated costs. Such degree of detail was not however the purpose of this project.

1.1.3- Policy making in the Loire and in the Rhine: two different approaches

From a physical point of view, the Rhine and the Loire basins have some points in common, such as:

- main courses are among the largest in Europe, with more than 1000 km long each;
- they both combine a very wide range of hydrologic contexts: basically flash floods close to the spring, mainly fluvial floods in the middle stretches and sea influence in the deltas, with local combinations of different influences
- dramatic events occurred several times in the history of both rivers.

Yet, some significant differences must be pointed out, as they are closely connected to the way flood policies are designed, to the local concern for floods, to the image each of the two rivers are associated to, etc.:

- the transnational character of the Rhine is of major importance: flood policies are then elaborated in a very specific context, combining national approaches and multilateral co-operation
- main course of the Rhine is very much channelled while the Loire is often presented as the “last wild European large river”
- the Rhine experienced severe floods in recent years, in particular in 1993 and 1995 while no such event occurred in the Loire basin.

Given these differences, floods are addressed in quite different ways in the two basins. Therefore, it is necessary to describe more in-depth respective contexts.

i- The Rhine³

The International commission for the Protection of the Rhine (ICPR) has been created in order to ensure international co-operation for the management of the Rhine. ICPR organises co-ordination thus ensuring that all actions launched are coherent and homogeneous enough. As far as flood policy is concerned (a rather recent field of interest for ICPR), goals are set by ICPR and it then belongs to member states to

³ A basin profile as well as fiches describing measures are included in the annexes.

make decisions in order to achieve them. To a certain extent, goals may thus be completed in several different ways depending on national and local factors.

Following several flood events during the 1990's, ICPR decided to establish an action plan on floods [FLM09]. This document, adopted by member states in January 1998, identifies 4 key goals:

- reduce damage risks: no increase by 2000, -10% by the year 2005; -25% by the year 2020
- reduce flood levels downstream of the regulated Upper Rhine by up to 5 cm by 2000, by up to 30 cm by 2005 and by up to 70 cm by 2020
- increase flood awareness: drafting risk maps for 50% of the floodplains & flood prone areas by the year 2000 and 100% of such areas by 2005
- improve the flood announcement system: increase warning lead time by 50 % until 2000 and by 100 % until 2005

Given these objectives, the action plan identifies several measures that should be taken by member states. Measures are synthesised in the following fiches and are associated with financial information. As ICPR has no executive power, the plan provides only guidelines to member states: each measure may be implemented in different ways and it belongs to each state to determine how to proceed given its specific context.

The table next page provides an overview of the action plan. The cost of the measures is 12 000 M€ by 2020. Detailed information on individual measures is available in the annexes.

No formal scenario has been designed prior to the elaboration of the action plan. The ICPR has produced an atlas of potential damages that covers the river course (without tributaries) [FLD03]. This is in fact not a “do-nothing” scenario but rather orders of magnitude of the maximum damages that could occur in each plot of the basin in case of extreme flood, desegregated into three categories: settlement, industry and traffic and agriculture. As stated in the atlas,

This document provides an overview of the location of most vulnerable areas, in terms of persons affected, of persons at risk and of material assets. The ICPR left it to member states and to local stakeholders to design proper scenarios before elaborating action plans at basin scale.

The calculation of potential damage in cases of extreme floods is based on the 4 steps:

- determination of land use in the areas at flood risk
- determination of people affected and persons at risk on the inundated surfaces
- determination of assets and values on the inundated surfaces
- determination of potential damages by applying a damage function to the different goods depending of flood depth.

Due to the size of the surfaces and the overview scale, several simplifications were required for each of these steps. The detailed methodology applied is provided in the atlas.

On this basis, it is estimated in the atlas that potential damages at basin scale amount for approximately 165 000 M€.

General overview of the action plan for the Rhine

Policy option	Basin flood management policy
Measure	Action plan
Location	Rhine basin

Fiche Code	BAS01
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Source of information	Plan d'action contre les inondations
Reference	FLM09

Description	<p>a) Flood risk mapping and communication</p> <p>b) Flood forecasting and early warning systems</p> <p>c) Measures reducing impact of flooding</p> <p>d) Limit the use of floodplains</p> <p>e) Increasing retention capability of soils</p> <p>f) Reduce level of flooding for given run-off</p> <p>g) Increasing retention capability of floodplains and wetlands</p>
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	Costs		Comments
Direct costs	Capital	a: 60 M€ e: 1 890 M€ b: 12 M€ f: 1 418 M€ c: 0 g: 7 215 M€ d: 1 705 M€	Overall cost of the plan for the 1998-2020 period is 12 300 M€ c: cost is to be born by individuals, companies, farmers... in order to reduce their vulnerability to flood risk
	Operation		
	Maintenance		

	Description	Costs	Comments
Benefits	Avoided damages	41 225 M€	Altogether, measures set in the plan shall lead to the reduction of damages by up to 25% by 2020 Calculation based on estimates of potential damages contained in the Rhine atlas: 164 900 M€ at Rhine scale.
	Others		Reducing extreme flood levels downstream the impounded section by up to 70 cm by 2020 Increasing of flood awareness: drafting risk maps for 100 % of the floodplains & flood prone areas by the year 2005 Improvement of the flood warning system: prolong the warning lead time by 100 % until 2005. Achievement of these goals will contribute altogether to the reduction of damages.

The action plan set objectives by 2020 (at the latest) in terms of flood policy. It also stated that interim reviews should be made to assess the degree of implementation of the measures. In 2000, the first evaluation consisted in the compilation of elements provided by member states detailing measures taken to fulfil the objectives set in the plan [FLM10]. It was supplemented by an interim report published in 2003 [FLM69]. A presentation of the level of achievement is provided in part 4.B below.

In 2005, a formal evaluation will be done, based on a specific approach: the level of reduction of the risk will be evaluated in concrete terms. Compared to 2000 evaluation, changes apply to:

- the scale: instead of national reports, member states are requested to elaborate reports at smaller scale. To this purpose, a dedicated working group has identified 15 sectors in the basin. Information on the implementation of the plan will be tailored at this scale, what enables to have a more precise view of what has been done.
- the methodology: the working group has elaborated a common methodology that shall be implemented by member states in preparing the evaluation. A specific methodology is defined for each criteria addressed in the “Non-structural flood plain management” ICPR publication [FLM12].

In 2005, the working group will then gather and consider all elements to build a homogeneous state of the play.

ii- The Loire⁴

Until the early 1990's, a key aspect of flood policy in the Loire basin consisted in the construction of large reservoirs under the auspices of local authorities [FLP12]. However, this generated strong opposition from ecologists and from a part of the population: only 1 reservoir was built out of the 3 that were planned.

This conflicting situation ended in a complete change of public policy decided by the central government in 1994 when a 10-year plan was launched: the “*Programme Loire Grandeur Nature*”. The idea was to lead to an open and transparent decision-making process, with a better combination of 3 key issues:

- reduction of flood risk,
- satisfaction of quantitative and qualitative water needs for all users,
- restoration of the basin's biodiversity.

300 M€ works were planned, including the construction of a strongly criticised reservoir.

In order to prepare this new policy, a multidisciplinary team was set: the *Equipe Pluridisciplinaire Plan Loire Grandeur Nature*. Among other activities, they have worked since then on the definition of a flood strategy for the Loire on behalf of the government, of the water agency and of the local authorities.

One of the very first tasks for the *Equipe* consisted in the definition of a strategy for the middle Loire, where 80% of stakes are located (largest urban areas, lot of economic activity, many urbanised sectors in flood prone areas...). On first level modelling activities were launched to simulate flood levels for several types of floods [FLM23] [FLM24]. Then, it was possible to combine this information with the characterisation of uses and activities in flood prone areas. This gave a good knowledge of the situation regarding stakes, their localisation and their vulnerability. This information was then turned into economic estimates of damages (see table below).

⁴ A basin profile as well as fiches describing measures are included in the annexes.

Stakes exposed in Middle Loire in case of a maximum flood (as in 1856) [FLD06] [FLD04]

115 000 dwellings – 290 000 inhabitants	78 500 ha traditional cultures
13 600 businesses – 71 500 employees	1 500 farms
1 650 public equipment	4 100 electricity transformers
165 water plants (drinking + wastewater)	1 000 electricity towers (25% in streams)
2 500 km roads (urban roads not included)	36 000 ha sites of ecological interest
8 200 ha specialised culture: vineyards, orchards...	216 monuments of historical interest

=> 3 areas concentrate 70% of population + 55% of economic activity + 60% of jobs + 84% of specialised agriculture
=> 80% of stakes exposed to the maximum flood (as in 1856) are located in the middle Loire, in 9 areas only.

The result showed that a “maximum flood” as in 1856 would cause 6 000 M€ damage, with uncertainty between 60 and 100% (see table below). This didn’t include indirect damages, evacuation of people, intangible damages, etc. This is considered as the “do nothing” situation.

These elements were then converted into monetary terms, applying unitary costs, based on statistics or experts’ judgements.

Estimates of potential damages (in M€) in the case no measures were taken

Return period	Damages to housing	Damages to economic activities	Damages to agriculture	Damages to public equipment	Damages to roads	Total
50 years	140	290	45	0	15	490
70 years	180	440	60	15	15	730
100 years	210	550	75	15	15	865
170 years	245	640	75	15	30	1 005
200 years	535	1 050	170	15	30	1 800
500 years	700	1 540	290	15	45	2 590
1856-like flood	1 600	3 980	410	45	15	6 050

Source: [FLP11]

It was then considered here that, given this level of uncertainty and the partial character of method used for appraisal:

- economic figures would not be more detailed: at basin scale, it is alleged that this would not be cost-effective: more precise figures would remain very uncertain and would not change global estimates
- economic figures would be kept at basin scale in order to limit uncertainty
- economic figures would be used for communication as they may easily be understood but that effort would be put on the appraisal of vulnerability. To this respect, list of criteria have been established later on
- benefits of a risk reduction policy have not been estimated as it was considered that such policy would leave a large role to local actors to determine the level of vulnerability they would accept. Therefore, the level of reduction would be far too uncertain.

While the initial approach mostly consisted in examining how to improve hydraulic control of the Loire, it soon became clear that this was not relevant, when hydraulic simulations were connected to estimates of potential damages in several situations [FLP11]. In fact, studies showed that vulnerability was high in all types of floods:

- for floods of return period of less than 100 years: damages of up to 800 M€, 20 000 inhabitants and 1 600 businesses exposed
- for floods of 100-year return period of: damages of up to 2 300 M€

- for floods of 500-year return period: damages of up to 3 000 M€
- in case of dykes failure, damages may increase by 1 000 to 2 000 M€ in the case Tours or Orléans were flooded, and may reach 6 000 M€ in the worst case, if all polders were flooded as in 1856 due to 150 breaches in levees.

The conclusion of this analysis was that continuous heightening and extension of dykes and levees would be endless and hopeless:

- the functioning of the Loire during floods is such (it may remove meters of sediments) that it may considerably weaken basis of dykes and levees thus seriously increase the risk of failure [FLP14];
- dykes failure is identified as factor number 1 for increase of damage;
- the vulnerability of activities keeps increasing as people feel over-secure behind dykes, what is a common drawback of this type of measure.

Given all these elements, public authorities decided that the reduction of hydraulic hazard would not ensure sufficient security to people and economic activities, particularly if protection works are not regularly maintained. This approach is in line with the 1996 Loire-Bretagne district management plan (SDAGE) that promotes the idea of “*living with floods*”. Indeed, as floods cannot be completely avoided, people shall learn how to cope with them:

- organise so that valuable goods are not exposed in case of flood;
- be well informed to act properly when flood arrives, etc.

In 1999, the *Equipe pluridisciplinaire* proposed a strategy [FLM11] based on 3 pillars, summarised as the “**3 P’s strategy**” [FLM14]:

- **P**rediction i.e. all measures likely to improve the monitoring, forecasting and alert capacities
- **P**revention i.e. non-structural measures: mapping, reduction of the use of floodplains, reduction of vulnerability, restoration of riverbed...
- **P**rotection i.e. structural measures: dykes restoration and punctual extension, flood peak shaving reservoir, very local protection works...

The construction of this strategy was based on the comparison of several options and combinations of measures [FLP11], considering their respective efficiency in terms of reduction of damages and of exposed stakes. A synthesis of this comparison is presented below.

As for the Rhine basin, this is not a proper scenario. Several policy options are compared, but are not put back to back with a “do nothing” situation.

Comparison of options for the Loire basin

			Basis	Scenario 1	Scenario 2	Scenario 3	Scenario 4					
DESCRIPTION			Measures (a, c, h) + (b, d, g) + maintenance of dykes (part of f)	Basis + new dykes (part of measure f)	Basis + new weirs (part of measure e)	Basis + flood peak shaving work (part of measure e)	Basis + Scenario 1 + Scenario 3					
COSTS (M€)	Capital		80 - 102	217 – 407	91,5 - 125	156 – 254	293 – 581					
	Operation		3,5 - 5	4,2 – 5,7	3,5 - 5	4,2 – 5,7	4,9 – 6,4					
DAMAGES (M€)	Hypothesis 0	AAD	31	27	31	27	23					
		Gain	-	4	0	4	8					
	Hypothesis 1	AAD	35	28	35	30	24					
		Gain	-	7	0	5	11					
	Hypothesis 2	AAD	41	29	40	33	24					
		Gain	-	12	1	8	17					
COMMENTS				Balance between cost of measures and gain (i.e. avoided damages) similar to scenario 3.	Very limited gain. Does not include positive impact of weirs (on population, on environment) linked to their influence on flood spreading.	Balance between cost of measures and gain (i.e. avoided damages) similar to scenario 1.	Significant reduction of damages compared to other scenarios. E.g. double than scenario 3. Cost is 2 times higher too.					
			Population	Industrial sites	Population	Industrial sites	Population	Industrial sites	Population	Industrial sites		
STAKES	RP 50 yrs	Number	25 000	1 800	24 500	1 800	-	-	21 500	1 300	20 000	1 300
		Gain	-	-	500	0	-	-	3 500	500	5 000	500
	RP 100 yrs	Number	38 500	2 800	33 000	2 400	-	-	34 000	2 300	30 000	2 200
		Gain	-	-	5 500	400	-	-	4 500	500	8 500	600
	RP 170 yrs	Number	46 000	3 200	38 500	2 900	38 500	2 900	41 000	2 900	33 500	2 600
		Gain	-	-	7 500	300	7 500	300	5 000	300	12 500	600
	RP 500 yrs	Number	120 500	5 900	100 000	5 400	120 500	6 000	118 000	5 800	98 000	5 400
		Gain	-	-	20 500	500	0	-100	2 500	100	22 500	500

Legend

Contents of all measures are detailed in the fiche next page
 Hypothesis 0: flood “only”

Hypothesis 1: hypothesis 0 with dykes failures and groundwater upflow, level 1
 Hypothesis 2: hypothesis 0 with dykes failures and groundwater upflow, level 2

AAD: annual average damage
 RP: return period in years

Given the idea that focus shall be put on reduction of vulnerability, the basic measures considered in the scenarios (“Basis”) are integrated in all options: they are considered as a compulsory set of measures no matter strategic choices made. Indeed, it is estimated that the reduction of vulnerability of existing stakes could lead to a 10 to 15% reduction of damages in case of flood. Efficient post-crisis management could lead to a further 10 to 15% reduction of damages.

Based on the analysis of these various alternatives, scenario 4 was proposed as the strategy for the Loire and was turned into the action plan. A general overview is provided next page, measures are detailed in the annexes.

General overview of the action plan for the Loire

Policy option	Basin flood management policy
Measure	Action plan
Location	Loire basin

Fiche Code	BAS02
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Source of information	Synthèse des propositions pour une stratégie globale de réduction des risques d'inondation par les crues fortes en Loire moyenne
Reference	FLP11

Description	a) Flood forecasting and early warning systems b) Public awareness on best practices c) Establishment of an emergency plan	d) Limit the use of floodplains e) Measures to reduce peak run-off f) Reduce level of flooding for given run-off	g) Measures reducing impact of flooding h) Implementation of emergency plans
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	Costs		Comments
Direct costs	Capital	a+c+h: 7,6 M€ b+d+g: 61 to 76 M€ e: 87,5 to 175 M€ f: 148 to 324 M€	Overall capital cost of the action plan rises up to 583 M€ Level of investment depends on the level of security sought: - to face flood with 100-year return period: between 122 and 305 M€ - to face flood with 170-year return period: between 230 and 460 M€ - to face flood with 500-year return period: between 305 and 583 M€ The highest investment would ensure protection of the entire Middle Loire for flood with 200-year return period.
	Operation	a+c+h: 1,2 M€ d: 0,76 M€ b+d+g: 0,76 M€ e: 2,56 – 3,76 M€	Annual overall operation cost is between 5,28 and 6,48 M €. This amount depends on the level of investment rather than on the flood return period. It is approximately twice the current annual expense (figure 1999).
	Maintenance		

	Description	Costs	Comments
Benefits	Avoided damages	b+d+g: the reduction of vulnerability of existing stakes could lead to a 10 to 15% reduction of damages h: Efficient post-crisis management could lead to a 10 to 15% reduction of damages	h: inadequate crisis management is likely to increase damages by 10 to 100%
	Others	e: flood peak shaving potential ranks between 600 - 900 m ³ /s for flood with respectively 50 - 1000 return period. Flood level reduction is between 20 - 50 cm upstream Tours and between 5 - 20 cm downstream, what is significant esp. in urban areas where riverbed is narrow.	f: poor maintenance of riverbed may lead to increase of river flow by 30 - 70 cm, esp. where the stream is narrow (urban sectors)

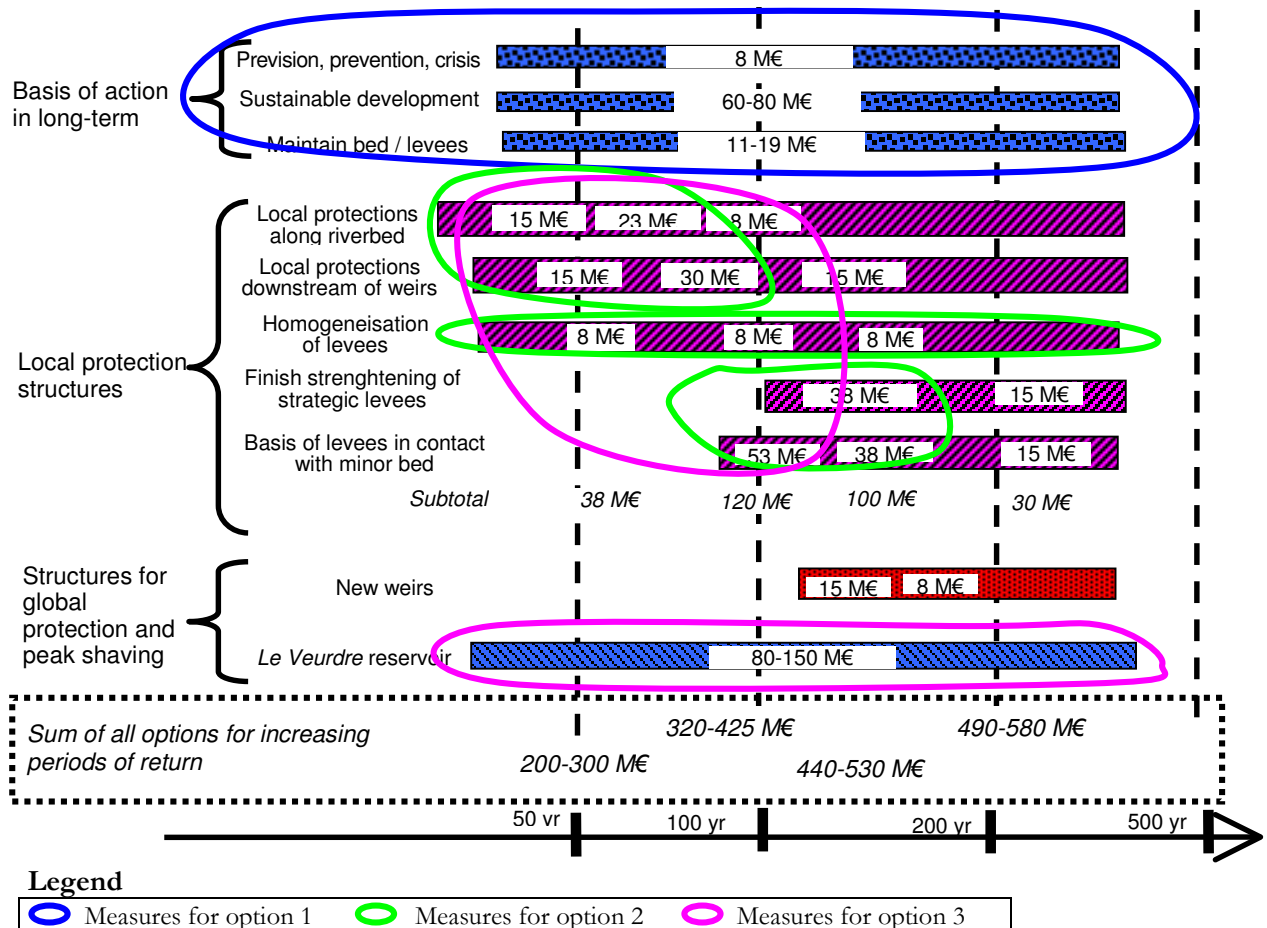
No period is indicated for this plan: it is in fact referred to as a strategy that shall be implemented as soon as possible, but with no formal deadline.

Given the identification of this strategy as the optimal combination of measures, attention was paid to hypothesis in which financial constraints would lead to partial implementation.

Depending on the available funds, the following was proposed [FLM21] [FLP15]:

- option 1, for around ~100 M€: basis of action should be considered as a compulsory minimum policy. This amount is similar to budgets planned at Loire scale under “*contrats de plan*” mentioned below. This option is thus realistic in financial terms;
- option 2, for ~150 M€, basis could be supplemented by different types of local protections, depending on priorities: a) protection of areas with biggest stakes (then consider floods with 120- to 150-year return period); b) protection of areas exposed to overflows (then consider floods with 70- to 100-year return period); c) protection of areas most frequently flooded (then consider floods with 30- to 70-year return period). Choice and combination among these “alternatives” would certainly be very difficult both from political and from technical (coherence?) points of view;
- option 3, for ~200 M€, basis could be supplemented by elements of the 3 “alternatives” of option 2 or by the construction of the reservoir in Le Veurdre;
- options 4 and 5, for 450 to 600 M€, the complete strategy could be implemented, taking into account that case 4 would be a minimum budget and would certainly require to make choices among some of the measures. In both cases, a good level of safety would be ensured for flood with ~200-year return period.

These simulations are illustrated in the following figure.



In practice, public authorities have never formally validated this strategy at basin scale, for several reasons. The key reason is that the proposed policy is a very demanding approach: the selection of measures shall be based on a multi-criteria analysis, including identification and ranking of key criteria and concluded by an open discussion in order to make choice.

Equipe Pluridisciplinaire has done works on the first two stages in order to provide tools but the decision necessarily belongs to local actors. It means time, transparency, open decision-making process and for all these reasons, it has not been implemented.

Thus, in broad terms, minimum actions are carried out: the necessary ones (e.g. forecasting, maintenance of dykes) and the cheapest ones. More detailed elements are provided in part 4.B below.

1.1.4- Example of a flash flood basin: the Vidourle⁵

The Vidourle basin doesn't have much in common with the Loire and the Rhine ones:

- it is a small basin: the main course is 100 km long, the surface of the basin is approximately 850 km² and only 110 000 inhabitants live there;
- from a geographic point of view, it is a coastal river. Flash floods are so much a part of the local culture that they are called "*Vidourlades*";
- though local authorities have gathered into a *syndicat* in order to design and carry out policies at basin scale (quality of the water, floods, river engineering, tourism, protection of the aquatic environment...), capacity and expertise cannot be compared to that of the ICPR or *Equipe Loire*. The *syndicat* for the Vidourle is an operational institution focusing on field activities what is very different from the other two institutions that rather have a policy-making purpose.

This *syndicat* gathers 94 municipalities and 2 departments; it is in charge of the management of the river and has a specific mandate regarding floods. It co-ordinated the preparation of the plan and is responsible for the follow-up of the implementation and of the execution of some measures (e.g. construction of flood protection works). Several measures are under the responsibility of other actors, esp. municipalities.

The *syndicat*, created in 1989, has carried out lots of works in the basin: restoration of riverbanks and of dykes, scrub clearing of riparian areas, restoration of oxbows, etc. Over the 1990's, more than 6 M€ have been invested for such works, of which 3 M€ for the reinforcement of dykes. Though most of these activities contributed (directly or not) to the reduction of the impact of floods, no formal policy was designed to this regard at that time.

Then, a dramatic flood occurred in 2002: in the Vidourle basin, 22 persons were killed; one of the main city was under 4m of water for some hours. Damages in the whole flooded area (larger than the Vidourle basin) amounted for more than 1 000 M€ [FLM31]. This event profoundly shocked the population and the decision-makers. Six months later, a 4-year action plan was issued [FLM36], which was awarded specific financial support by the Ministry of the environment (3 other plans were so selected among 130 'candidate plans' from all over the country): 40% subsidies out of 29 M€ for full implementation. Given this specific context, no formal procedure was followed to prepare the plan: establishment of scenarios and comparison with a "do nothing" option, economic analysis of measures, etc. The plan contains measures that are judged relevant and financially realistic by decision-makers and local experts.

When looking at the action plan it appears that the geographic and hydrologic peculiarities of this basin do not lead to specific "flash floods measures". A lot of attention is awarded to the reduction of vulnerability (adaptation of exposed goods, changes in agriculture practices...) as it is admitted that hydraulic measures do not suffice to ensure a good level of safety. Yet, though hydraulic constraints are specific in flash floods basins, such approach is not specific to such basins. Most plans include such measures, no matter the type of flood and of basin (see a general overview of the measures next page).

The plan is probably more typical of a plan designed right after a dramatic flood, in time of major concern

⁵ A basin profile as well as fiches describing measures are included in the annexes.

General overview of the action plan for the Vidourle basin

Policy option	Basin flood management policy
Measure	Action plan
Location	Vidourle basin (F)

Fiche Code	BAS06
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Source of information	Projet de plan de prévention des inondations sur le bassin de la Vidourle
Reference	FLM36

Description	a) Flood forecasting and early warning systems	d) Measures to reduce peak run-off
	b) Public awareness on best practices	e) Reduce level of flooding for given run-off
	c) Establishment of an emergency plan	f) Measures reducing impact of flooding

		Costs			Comments
Direct costs	Capital	a: 0,19 M€ b: 0,05 M€	c: 0,95 M€ d: 9,25 M€	e: 10,37 M€ f: 6 M€	Overall investment costs are estimated for 26,81 M€ i.e. 93% of the overall costs.
	Operation	a: 0,08 M€			
	Maintenance				

		Description	Costs		Comments
Indirect costs	b: 5 persons full-time	e: 1 person full-time	b: 0,8 M€	e: 0,16 M€	Indirect costs only include wages for the duration of the plan. They amount for 1,94 M€ i.e. 7% of the overall costs.
	c: 1 person full-time	f: 2 persons full-time	c: 0,16 M€	f: 0,32 M€	
	d: 3 persons full-time		d: 0,5 M€		

		Description	Comments
Benefits	Avoided damages		
	Others	Share of rainwater shaved: - approx. 16% of rainfall in each sub-basin for 10-year return period rains - approx. 18% of rainfalls at basin scale in case of 50-year return period rains	Benefit expected from measure d.
		Better knowledge of risk and of stakes Securisation of dykes Reduction of hazard in 2 towns Dynamic slowdown of floods	Benefit expected from measure e.

The plan covers a 4-year period (2003-2007). A key aspect of this plan is that 7% of the overall costs are clearly awarded to human resources, with the creation of 12 full-time jobs. This stresses on the importance of the human factor as part of flood policies: infrastructures and equipment are not all.

1.2- State of the art. Existing policies with an impact on flooding

1.2.1- WFD

The Water Framework Directive (WFD)⁶ is currently the most influential factor for water policy in Europe since it shifts the focus of policy-making from singular problems to integrated river basin management. Article 1 of the Directive not only requires Member States to achieve ecological standards for waters, but also lists “mitigating the effects of floods and droughts” among the objectives of the directive. Precautionary flood protection, however, is not explicitly addressed in the Directive.⁷ An indirect link can be made, given that the Directive demands that there be no further deterioration of river systems. Furthermore, the Directive places greater emphasis on the preservation of wetlands and floodplains, and the structural / hydromorphological quality of water bodies. Furthermore, by establishing a comprehensive river basin planning approach, the Water Framework Directive offers an opportunity to re-orient water management in a way that protects the environment and people from the damaging effects of flooding.

1.2.2- Common Agricultural Policy

Even though flooding is not directly addressed within the regulation defining the Common Agricultural Policy (CAP)⁸, their 2003 revision offers several possibilities for flood prevention.

- *Decoupling* (first pillar of the CAP) will phase out incentives to increase or intensify production to optimise direct payments. Farmers can extensify their production without losing their payment entitlements, which may *inter alia* be used to enhance the water retention capacity of soils;
- *Cross compliance* (first pillar of the CAP) provides for maintenance of good agricultural and environmental conditions, which is especially important for soil-related issues;
- The Proposal for a *Rural Development Regulation* (second pillar of the CAP), which is currently negotiated, could provide crucial opportunities for Member States to fund measures related to flood prevention and protection within their Rural Development Programmes.

1.2.3- European Policy in the Area of Soil Protection

Floods are intimately related to soil and land management. Floods may cause or reinforce erosion, and may lead to the pollution of watercourses and floodplains with contaminated sediment, with major impacts for human activities and human lives, damage to buildings and infrastructures, and loss of agricultural land. At the same time, soil degradation reduces the capacity of soils to absorb and retain precipitation, increasing rainwater runoff and thus contributing to floods. In order to address these

⁶ European Parliament and the Council (2000) Directive of the European Parliament and of the Council concerning establishing a framework for community action in the field of water policy (2000/60/EC), 23 October 2000.

⁷ Article 4 WFD mentions overriding flood protection requirements among the possible reasons why a water body may be designated as heavily modified. In addition, extreme flooding events are identified as one possible justification for a temporary derogation.

⁸ Council Regulation (EC) No 1782/2003 of 29 September 2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers and amending Regulations (EEC) No 2019/93, (EC) No 1452/2001, (EC) No 1453/2001, (EC) No 1454/2001, (EC) 1868/94, (EC) No 1251/1999, (EC) No 1254/1999, (EC) No 1673/2000, (EEC) No 2358/71 and (EC) No 2529/2001 Official Journal L270 of 21.10.2003, p. 0001 - 0069

⁹ Council Regulation (EC) No 1783/2003 of 29 September 2003 amending Regulation (EC) No 1257/1999 on support for rural development from the European Agricultural Guidance and Guarantee Fund (EAGGF) Official Journal L 270 , 21/10/2003 p. 0070 - 0077

issues and several other soil threats, a Thematic Strategy on Soil Protection is currently under development. In April 2002, the European Commission proposed some essential components for such a Thematic Strategy, which identifies eight different soil threats, among them floods and landslides (as one combined threat).¹⁰ The strategy itself is now expected for 2005.

The proposal for a Thematic Strategy on Soil Protection drawn up by the EU Commission underlines that the integration of flood risk management and soil protection remains a difficult challenge. For the future development of the strategy, clear targets for reversing soil compaction and sealing could provide a valuable contribution to flood risk management.

1.2.4- Financial sources

Financial sources will play a major role in future measures on effective flood prevention, protection and mitigation. Currently, the EU has different structural funds at the European level that provide Member States with an alternative to national funds:

- The European Regional Development Fund (ERDF) was created to reduce regional disparities in the Union, while at the same time encouraging the development and conversion of regions^{11 12};
- The European Agricultural Guidance and Guarantee Fund (EAGGF) supports economic and social cohesion policy, rural development and the improvement of agricultural structures¹³;
- The LIFE Financial Instrument for the Environment contributes to the development of innovative techniques and methods by co-financing demonstration projects ¹⁴;
- The European Union Solidarity Fund (EUSF) was set up three months after the floods of August 2002 and provides rapid financial assistance in the event of major disasters which includes flooding¹⁵.

The first three funds essentially focus on accomplishing specific tasks (e.g. environment, specific regions and areas), not on the issue of flooding. Beside other issues, they could also be used to finance precautionary flood protection measures.

1.2.5- National legislation

At the national level, most European countries have different regulations and responsibilities for flood protection and flood risk management, including civil protection. Both issues are regulated by different laws (planning, water, housing, environmental, civil, nature conservation, agriculture). This may not only lead to conflicting responsibilities and objectives within Member States; European countries also focus on different aspects of flooding. For example, Germany focuses on precautionary measures,

¹⁰ Commission of the European Communities (2002): Communication of the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the regions. Towards a Thematic Strategy for Soil Protection, COM(2002) 179 final, Brussels, 16. April 2002.

¹¹ The Council of the European Union (1999): Council Regulation (EC) 1260/1999 Laying down general provisions on the Structural Funds, Official Journal L 161/1999 of 26. June 1999.

¹² The Council of the European Union (1999): Council Regulation (EC) 1257/1999 On support for rural development from the European Agricultural Guidance and Guarantee Fund (EAGGF) and amending and repealing certain Regulations, Official Journal L 160 of 26. June 1999.

¹³ The Council of the European Union (1999): Council Regulation (EC) 1783/1999 On the European Regional Development Fund, Official Journal L 213/1999 of 13. August 1999.

¹⁴ The Council of the European Union (2000): Concerning the Financial Instrument for the Environment (LIFE), Official Journal L 192 of 28. July 2000.

¹⁵ The Council of the European Union (2002):- Council Regulation (EC) No 2012/2002 establishing the European Union Solidarity Fund, Official Journal L 311 of 14. November 2002.DN: IP/02/1662 Date: 13/11/2002.

while Poland and the Czech Republic put most of their effort into flood management.¹⁶ Within the EU, civil protection is based on the Art.3 para.1(u) of the European Treaty,¹⁷ but has no specific laws regulating policy and procedures on this topic.

1.3- The developing European strategy on flooding – Basic principles

Since European water policy generally follows a river basin approach, this is also true for the developing European strategy on flooding. This is clearly outlined in the 2003 “best practice document” and in the Commission proposal on flood risk management. Based on this river basin approach, the following aspects have to be taken into account when developing effective flood risk management programmes:

- Prevention: preventing damage caused by floods by avoiding construction of houses and industries in present and future flood-prone areas; by adapting future developments to the risk of flooding; and by promoting appropriate land-use, agricultural and forestry practices;
- Protection: taking measures, both structural and non-structural, to reduce the likelihood of floods and/or the impact of floods in a specific location;
- Preparedness: informing the population about flood risks and what to do in the event of a flood;
- Emergency response: developing emergency response plans in the case of a flood;
- Recovery and lessons learned: returning to normal conditions as soon as possible and mitigating both the social and economic impacts on the affected population;
- Research: As a last point, it was agreed at the meetings in Budapest and Bonn that more research on flood-related issues is needed to gain a better understanding of the climatic, hydrological, ecological and landscape context of floods. Within the 5th and 6th Framework program several ongoing research projects are dealing with several issues of flooding¹⁸.

In the Communication, the Commission moves on to propose a Concerted EU Action Programme for flood protection, along with a list of features that should be included in order to address flooding on the river basin scale:

- a) improving co-operation and co-ordination through the development and implementation of flood risk management plans for each river basin and coastal zone where human health, the environment, economic activities or the quality of life can be negatively affected by floods. Solidarity and a common approach are essential, as passing water management problems from one region to another (e.g. upstream to downstream) is not a good option;
- b) developing and implementing flood risk maps as a tool for planning and communication;
- c) improving information exchange, sharing of experiences and the co-ordinated development and promotion of best practices;
- d) developing stronger linkages between the research community and the authorities responsible for water management and flood protection;
- e) improving co-ordination between the relevant Community policies;
- f) increasing awareness of flood risks through wider stakeholder participation and more effective communication.

¹⁶ BMU-Umwelt-Mitteilung 2001 - Hochwasserschutz an der Oder - ein trinationaler Rechtsvergleich vom 30. Mai 2001, more info at http://www.umweltbundesamt.de/wasser/veroeffentlich/bmu_umwelt/ikso.htm.

¹⁷ The European Communities 2001 - Treaty of Nizza, Official Journal C 80, 10. March 2001.

¹⁸ For further information see <http://www.eu-medin.org/floods-rtd-projects.php> or <http://www.cordis.lu>

It should be noted that these features, as well as the recommendations made in the best practice guidance document, are focussed on the institutional and procedural aspects of flood risk management rather than on concrete measures, be they technical, structural, non-structural or informational. This focus on institutional and procedural aspects is key to developing a common approach on the river basin scale: on the one hand, it offers an opportunity to jointly address problems that are common to the entire river basin, but on the other hand it also leaves sufficient leeway and flexibility for the practical implementation.

Part 2- Methodological background

2.1- Applied methodology

This analysis was based on a literature survey. Several types of documents have been collected: action plans, post event surveys, official reports, articles, policy papers, local authorities budgets...

Although our main concern was for the Rhine and the Loire basins, we collected information regarding other basins in order to widen the scope and relevance of analysis: Jucar, Meuse, Moselle-Sarre, Nahe, Lippe, Oise-Aisne, Saône-Doubs, Vidourle.

We carried out an extensive collection of documents:

- databases
- IOW's documentation centre "Eaudoc"
- websites of several institutions in charge of flood management in basins (see list in annexes)
- visits at ICPR and Equipe Pluridisciplinaire Loire
- Ministries for the environment in France, Germany and the Netherlands
- several contacts and interviews with experts from France, Germany, the Netherlands, Switzerland and UK (see list of contacts in annexes) provided both documents and discussions.

At this stage, it is important to stress that the research was based on the information that was available to us in the time of the project. E.g. in some cases, "grey literature" may exist but was not communicated. Existing information was then not necessarily available given these constraints.

From all these sources of information, we extracted several types of data such as: facts and figures, elements on costs (of measures and of damages), description of the elaboration process of measures and of their implementation, description of best practices and trends, identification of issues that are being discussed (e.g. integration of intangible damages into economic analyses, role for cost-benefit analysis in flood policy-making...), information on methodologies implemented, etc.

On this basis, we have established a typology of damages caused by floods (see part 3) and of measures implemented in flood management (see part 4).

There is a general agreement on the classification of damages, on 2 levels:

- tangible damages and intangible damages;
- direct and indirect damages.

This distinction is applied to all sectors likely to be affected by floods: housing, economic activities, agriculture, public buildings and networks, environment, human health.

Regarding measures implemented, distinction has to be made between theoretic classification on the one hand (e.g. structural and non-structural measures, prevention and protection measures...) and the action plans themselves on the other hand, as they don't pay attention to such "technical" distinctions.

Rather, their structure is led by political and communication concerns: it is indeed important to put clearly that a set of measures is dedicated at reducing damages, no matter whether it combines what experts would sort as information, prevention or protection measures.

All plans are closely linked to a local context, and although they basically combine the same types of measures, they are not formally structured in the same way. Therefore, for analysis purpose, it is necessary to organise information on a homogeneous basis. This is why we have established a typology of measures, structured in four chapters:

- information

- prevention
- protection
- emergency

Each of them gathers several measures (see part 4). All action plans considered and analysed during the project have been split into basic measures that have then been classified according to our typology. This approach loses the balance and cohesion of each individual plan but allows analysis and comparison of homogeneous measures.

In the Rhine basin (main river and tributaries) most plans were built on a common pattern. Therefore, in terms of analysis, as long as measures were similar and elaborated in the same context, we didn't consider each of such plans separately, as this didn't bring any new information and was rather redundant.

The organisation of information we implemented made comparison and analysis possible, as all descriptive data on measures and damages has been gathered homogeneously into fiches built on the same pattern¹⁹. Therefore, with information put as such, points in common, specificities and blanks (i.e. lack of information) appear clearly.

2.2- Classifications applied for the project

2.2.1- Typology of measures

Measures contained in action plans on floods are quite similar in fact, as the ultimate goal set to flood policies is everywhere the same: basically, the reduction of the risk of damages, in particular the risk for human life. On this basis, plans always combine the same types of measures, though with more room awarded to prevention or to protection, priority given to improvement of forecasting capacities, etc. Although several possible combinations may be implemented, basic measures combined are not of infinite diversity and are well identified [FLM03].

Therefore, it is possible to sort all measures contained in action plans against a common typology ensuring homogeneous classification and description of measures, then coherent analysis on a second stage (see table below).

Types of measures	Measures
Information	a) Flood risk mapping and communication b) Flood forecasting and early warning systems c) Public awareness on best practices d) Establishment of an emergency plan
Prevention	a) Limit the use of floodplains b) Increasing retention capability of soils c) Increasing retention capability of floodplains and wetlands
Protection	a) Measures to reduce peak run-off. <i>E.g. flood control/ emergency reservoirs</i> b) Reduce level of flooding for given run-off. <i>E.g. dikes</i> c) Measures reducing impact of flooding. <i>E.g. storage of valuable or environmentally harmful goods</i>
Emergency	Implementation of emergency plans

¹⁹ From a practical point of view, all fiches are placed in the annexes, only key information is presented and analysed in the report itself.

On this basis, an individual fiche has been prepared for each measure considered, as well as a synthesis fiche at plan scale in order to provide an overview. This is made even more necessary as benefits expected from plans are often appraised at plan or at group of measures scale.

Though each plan’s specific context has to be taken into account, this approach allows both a technical and a financial comparison.

All fiches are gathered in annexes; yet most interesting element from the action plans will feed the following parts of the report.

The main constraint when analysing the plans is that information is provided in line with each plan’s pattern. E.g. information on costs of the measures and on associated benefits. Therefore, although it is possible to split measures as they are organised in each plan in order to make them fit with our typology, this is not always possible with associated information.

2.2.2- Typology of costs

Two main types of costs are considered when working on flood policies:

- the costs of the measures implemented
- the costs of the damages generated by floods.

This section refers to the former type.

When designing the typology, two types of costs were identified:

Types of costs	Costs
Direct costs	capital
	operation
	maintenance
Indirect costs	

In practice, information found in action plans about the costs of the measures is very heterogeneous:

- in most cases costs refer only to investment costs;
- operation and maintenance costs are almost never mentioned;
- indirect costs are generally not taken into account.

Therefore, in most fiches describing measures, associated boxes have been deleted in order to ease reading.

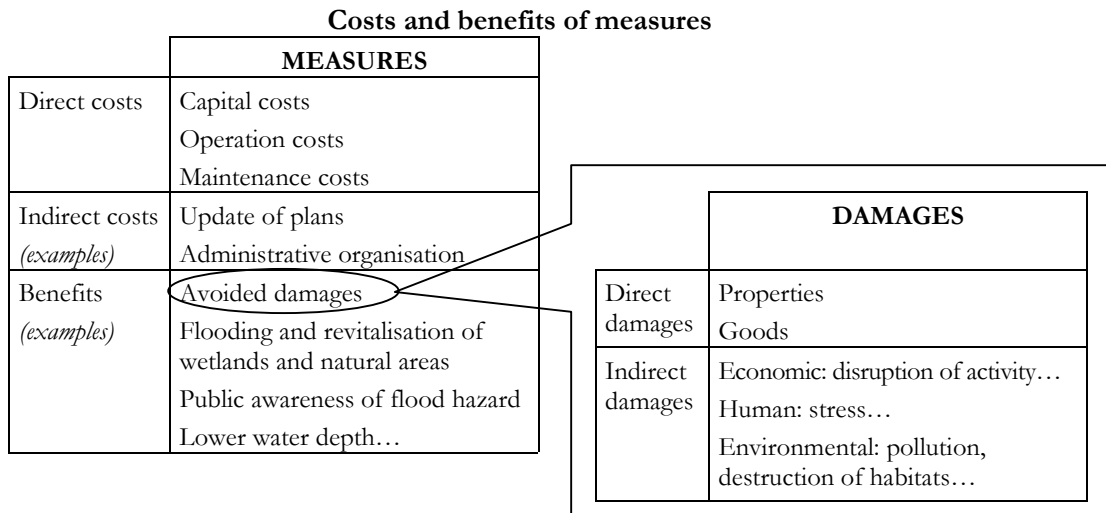
Another important point to bear in mind when considering costs of the measures is the “intention dimension”:

- figures provided in the plans are generally approximates in order to present rounded off results (e.g. “exactly” 500 M€ for the 1998-2020 Moselle-Sarre action plan [FLM63b]). Such symbolic figures also have a communicating goal;
- the longer the term of the action plan (e.g. 2020 for the Rhine [FLM09] or the Nahe basin[FLM50]), the higher the uncertainty regarding the real amount of implementation but also the reality of the expenditures.

Therefore, considering only figures from action plans may be misleading. It is thus necessary, whenever possible, to compare such announcements with assessments and figures on expenditures. This aspect is further developed in section 4.1.2.

2.2.3- Typology of benefits

First of all, it is important to clarify the use of the word “benefits”. Indeed, flood policies all target the same ultimate benefit i.e. the reduction of damages. Therefore, in most cases, benefits generated by the measures implemented are quantified in terms of avoided damages (see figure below).



In practice, action plans collected hardly connect measures and expected benefits: rather, general goals such as “the reduction of damages” or “the extension of warning period”.

Next to these goals, sets of measures are proposed, described and quantified. Yet, direct connection is hardly made, partly because expected benefits remain as general goals at plans scale and are generally not quantified. Indeed, benefits expected from a given measure are generally not individualised: the measure is supposed to contribute to the overall goal.

Some properly speaking “benefits” are also expectable from measures, in particular environmental ones. Indeed, flooding some floodplains, oxbows and wetlands may allow some forms of aquatic life to develop. Yet, no literature on this aspect was found.

As appears on the figure above, avoided damages are only one type of benefits. Yet, others are scarcely documented: either they are not considered as an ultimate benefit by themselves (e.g. awareness of the public is aimed at as it leads to a reduction of damages) or they are hardly paid attention as part of flood policies (e.g. good functioning of wetlands²⁰).

Besides, as this project focuses on economic aspects, it is clear that most relevant literature on this aspect deals with avoided damages. This doesn’t necessarily mean that interest only goes to tangible damages: research is carried out in order to take account of non-monetary damages, such as stress, health impact...

²⁰ Documents collected as part of the project only mention the positive role of wetlands only in general terms, seen from the flood side i.e. flooding wetlands will reduce the level of water in rivers. The environmental side of this flooding of wetlands (revitalisation, etc.) is not addressed in literature gathered.

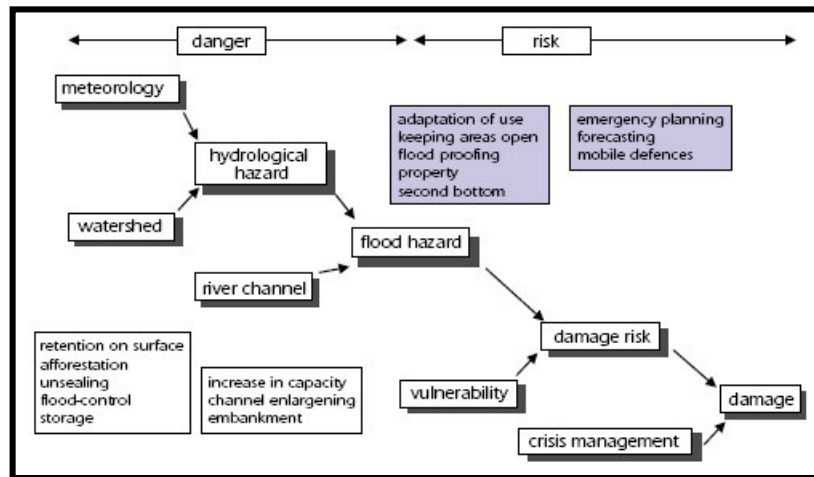
Given this specific context, benefits generated by flood policies will only be addressed as avoided damages in this project, against the following typology.

Types of damages	Sub-categories / Examples
Damages to housing	Buildings Movable properties
Damages to economic activity	Infrastructure, buildings, machines... Disruption of production
Damages to agriculture	Infrastructure Crops and cattle
Damages to public buildings	Buildings Movable properties
Damages to public networks	Roads, railways Distribution of drinking water and collection of wastewater Electricity networks
Intangible damages	Casualties Human health and well-being Environment

Part 3- The identification of damages and of associated costs

Several factors have impact on the level of damages: they are the result of a combination of factors and events of physical and human origins in broad terms. Figure below illustrates clearly the chain of damage generation.

Chain of damage generation



Source: [FLM12]

While traditional flood policies focused on physical factors, growing attention is paid to the human aspect for several reasons:

- urbanisation behind dykes increases the risk of damages in the case of breach
- standard of life leads to increase of the value of goods potentially exposed to floods
- people’s behaviour in time of flood may have positive or negative effect on the damages. E.g. removal of furniture on first floor may preserve them; drive one’s car on a flooded road is a frequent cause of death. This is closely linked to awareness of the risk and of the potential consequences.

Parallel to measures on the physical factors of the chain of damage generation, literature shows that measures targeting this human dimension, referred to as vulnerability, are getting common.

In basins considered with highest attention in the project, recent floods have caused high damages (see table).

Examples of estimates of damages caused by floods in selected basins

River basin	Date of the flood	Amount of damages	Source	Comments
Rhine	1999	40 M€	FLD17	District of Bern, Switzerland
	1993 / 1995	Billions €	FLM09	Rhine basin at large
		>50 M€	FLM50	Nahe basin, Germany
Loire	No recent flood	500 to 6000 M€	FLP11	Estimates for -flood with 50-year return period - 1856-like flood, with lots of dyke failures
Vidourle	2002	<1000 M€	FLM36	Data is only available at department scale, which is larger than the Vidourle basin. This is why different estimates are proposed
		816 M€	FLM35	
Meuse	1993	115 M€	FLD14	French part of the basin
		122 M€ / 106 M€	FLM13 / FLD14	Dutch part of the basin
	1995	240 M€	FLD14	French part of the basin
		26,5 M€	FLD14	Belgian part of the basin
		88 M€ / 66 M€	FLM13 / FLD14	Dutch part of the basin

3.1- Introduction

There is a general agreement on the classification of damages, on 2 levels:

- tangible damages, that can be quantified in monetary terms, and intangible damages that are not estimated as such as they don't affect economic values (e.g. human life, loss of environmental value);
- direct damages that are caused by the flood itself (e.g. destruction of buildings), and indirect damages that are secondary effects of the flood (e.g. disruption of activity due to the destruction of buildings).

This distinction is applied to all sectors likely to be affected by floods: housing, economic activities, agriculture, public buildings and networks, environment, human health.

3.1.1- Identification of damages

Main categories of damages may be summarised as follows.

	Direct damage	Indirect damage
Crafts, trade, industry	Loss of material, tools, stock Loss of furniture and archives	Expenditure for cleaning up Expenditure for moving Loss of exploitation
Farms	Damage to annexes Loss of material, tools, stock Loss of livestock and harvest	Loss of exploitation Loss of production
Individual housing	Damage to real estate Loss of furniture and assets	Expenditure for rehousing Expenditure for cleaning up
Public services and network	Loss of real estate Loss of equipment	Expenditure for cleaning up Expenditure for organising rescue and substituting services
Cultural heritage, environment	Damage to cultural heritage (incomplete evaluation)	Expenditure for restoration work
Local economy		Drop of finances, future income, value of real estate

Source: [FLM12]

Most damages listed in this table are tangible ones. Though only partially listed (damages to cultural heritage and to the environment), intangible damages are one of the major categories. Indeed, people affected by floods often rank them as such [FLP26]. Besides, casualties are also to be listed among potential damages, though they cannot be considered on the same level as damages to vehicles or to roads.

As detailed in Part 2, data collected has been organised in a typology of damages established for the purpose of the project.

3.1.2- Identification of associated costs

In many cases, data on the costs of damages is only partial and approximate. However, it remains possible to rank the importance of damages to each economic sector. Such information is useful in order to determine priority sectors. For the future, it also gives indications for the selection of measures.

Yet, a fundamental difficulty is to estimate *all* costs [FLD26]. Costs of direct damages provide a partial view of the situation and generally give punctual information, in the short term, but many indirect damages occur in the medium or long term. E.g. individuals feel stress every time there is severe rainfall, businesses may face difficulties in recovering a normal situation (the same clients...). All these damages are not proportional to the real cost of damages and deserve attention: individuals often suffer more from such indirect damages [FLP26][FLD25].

Availability of data is also a key for the appraisal of damages. Two different approaches have been developed to adapt to different national situations: depth-damage curves and unit loss approaches, the latter requiring detailed databases on the values of buildings and contents at risk [FLP26].

Similarly, damage data may come from surveys to affected people, to loss adjusters, etc. or from synthetic approach assessing mean losses per typical property type. Approaches are different and provide a different type of information, each having specific advantages and disadvantages. The latter method relies very much on experts' judgement and contradictory opinions on this method are found: though it led to positive results in UK [FLP26], experience in the Loire showed some reluctance from experts to take part to such exercise [FLM35].

As far as economic estimates are concerned, we find two ways of considering costs of damages in literature: either *ex post*, ie. based on real figures, or *ex ante*, ie. based on estimates.

i- *Ex-post* figures on damages

These figures are observed following flood events: they are then based on several sources such as insurance companies, local surveys, compilation of reports from the local administration, etc. Information appears to be very sparse in such cases, and estimates are always approximate. E.g. in most countries, insurance data is partial as it refers to level of indemnification, thus based on discounted values, which may be (far) different from renewal cost of destroyed goods: it is considered that real cost is 1,5 to 1,7 times higher than the level of indemnification²¹ [FLD14][FLD08][FLD05]. Given the large number of sources, it is hardly possible to make comparisons, as degree of detail of information is very variable.

At this point, a specific mention shall be made regarding the situation of flood damages in England and Wales²². Very detailed tables of costs of damages are provided nationally; they are primarily used for cost benefit analyses of planned flood risk management. These figures are based on *ex-post* observations. Until recently, they were based on 1990 data and were regularly updated. Although the retail price index could be used to update the 1990 values for inflation, it was well recognised within the industry that by 2001 the values presented a decade earlier underestimated potential damages by a factor of two to four due to social changes. Practitioners thus considered that reference data were obsolete [FLM35]. E.g. in the domestic sector, new electronic and video appliances with high economic value and greater susceptibility have spread. E.g. use of garages and underground floors in houses has strongly developed in UK for leisure activities or for living, what is likely to increase level of damages.

In 2003 an updated manual detailing their methodology and new depth damage figures (Multicoloured Manual (MCM)) was released [FLD12]. These updated figures have taken into account changes in prices and social trends. This manual is fairly extensive in its coverage of different types/ages of residential properties and non-residential property data. The updated figures took account of significant changes in the structure and contents of houses and of changes in attitude and approach to rehabilitation and repair.

²¹ This is exactly the opposite in the UK. Indeed, indemnification is based on replacement value whereas official figures used in cost-benefit analyses are calculated with economic value: assets are supposed to have 50% of their original value [FLD12].

²² Information on the English case was provided by ATKINS Water consulting.

ii- *Ex-ante* figures on damages

These figures are based on linear damage functions. These may be more or less fuelled with real data. Appraisal methods may be more or less refined, taking into account more or less types of damages. Trend is often to increase the number of categories then to individualise as much as possible such estimates as global calculations are not very realistic. Damage functions applied in different European countries may differ by a factor of 2 to 5 [FLM12].

In all cases, intangible damages are difficult to appraise. When this is done, it is often at a very small scale, what reduces reliability of comparisons and possibilities of analysis.

1993 flood of the Meuse in the Netherlands raised the question of reliability of *ex-ante* estimates *vs* occurred damages. Indeed, real figures regarding damages to furniture and houses are very much lower than estimated ones (table below).

Damages to furniture and houses compared to water depth

Class of water depth (m)	Cost of damages to furniture			Cost of damages to houses			Total cost of damages		
	Occurred damage (Fl)	Theoretic damage (Fl)	Over-estimation (%)	Occurred damage (Fl)	Theoretic damage (Fl)	Over-estimation (%)	Occurred damage (Fl)	Theoretic damage (Fl)	Over-estimation (%)
0 - 0.2	4 064.15	10 629.88	161%	5 933.56	1 179.68	-80%	9 988.76	11 809.56	18%
0.2 - 0.4	6 384.81	25 467.16	299%	8 216.50	3 238.58	-60%	14 598.04	28 705.74	97%
0.4 - 0.6	8 205.77	36 334.95	342%	9 309.60	5 361.01	-42%	17 515.38	41 695.96	138%
0.6 - 0.8	10 445.05	43 153.84	313%	9 993.28	7 455.25	-25%	20 438.32	50 609.09	148%
0.8 - 1	10 216.16	46 820.50	358%	10 033.66	10 023.32	0%	20 249.82	56 843.82	180%
1 - 1.5	10 374.62	47 803.43	360%	10 158.24	13 993.96	38%	20 352.86	61 797.39	204%
1.5 - 2	5 180.82	49 492.07	855%	7 760.30	21 314.73	175%	12 941.12	70 806.80	447%
2 - 2.5	7 116.19	54 254.31	662%	7 638.59	31 670.86	314%	14 754.78	85 925.17	482%
2.5 - 3	6 727.27	62 645.92	831%	11 638.92	57 330.93	392%	18 366.19	119 976.85	553%

Source: [FLM13]

On first approach, following comments may be made:

- this is only one example, maybe such differences do not always appear. Figures shall be analysed very carefully thus.
- theoretic damages have been calculated based on a past flood (1953) and on damage functions. The 1953 flood used as a reference was quite different from a hydraulic point of view: it came from the sea, there was no warning, etc.
- linear estimates are to be discussed when considering occurred costs, both on the principle of linearity but also regarding the degree of increase: it is much lower in reality than in estimates: damages to furniture increase only by a factor 2.5 between the lowest and the highest cases, when estimates increase by a factor 6 (respectively factor 2 and 48 in the case of damages to houses). Further investigations would be necessary to fully explain variations of curves of occurred damages (increase, decrease, increase).
- over-estimation is at the highest in the case of damages to furniture (between +300 and +800%). Value of furniture is certainly very much variable in time, depending closely on the standard of life of owners, the cost of goods, etc. while value of houses is likely to remain more stable in time. For lowest classes of water depth, theoretic values are even under-estimates.
- the question of the reliability of estimates is fundamental, as such figures are generally used to justify measures. In many places where there has not been any significant flood recently (e.g. Loire), figures used may be very far from potential reality. This aspect raises a key methodological question.

In the case of UK, the detailed methods developed provide a reasonably accurate and robust estimate of flood damages, particularly for residential property, based on those experienced in actual events. A major post event valuation study was carried out [FLP29] after the extensive flooding in Autumn 2000 that affected some 10,000 properties and data from this was one factor in the most recent update of the damage tables. The residential property damage assessments developed by the Flood Hazard Research Centre (FHRC) at Middlesex University are built up from very detailed individual costings for replacement or repair of building elements and items of household inventory. E.g. 5 types of residential property are identified (detached, semi-detached, terrace, bungalow, flat) then divided into 34 sub-types depending on their age, and 159 household items categories are considered.

3.1.3- Share of different types of damages

Another issues regarding damages is the share of the different types of damages that may occur: to housing, to industry, to agriculture, to public equipment, to the environment. No real trend appears as this share is widely linked to the types of uses of land for instance (e.g. in urban sector *vs* in rural area). The following table is an attempt to compare economic data from 8 recent floods in France. As local sources of information are sparse and very diverse, categories proposed in this table are not fully homogeneous. They are *ex-post* estimates; data from [FLD14] include only direct costs whereas other sources include both direct and indirect costs.

Comparison of costs of damages of some recent flood events in France (in M€)

Event	Houses	Economic activity	Agriculture	Roads and networks	Rescue	Overall cost	Source
France, 1977-78	20	22	34	38	0,5	115	[FLD14]
%	18	19	29	33	<1	100	
Nîmes, 1998	157	245	-	236	(a)	637	[FLD14]
%	25	38	-	37	-	100	
Vaucluse, 1992	23	23	24	50	6	125	[FLD14]
%	18	18	19	40	5	100	
Orb, 1995-96	11 (b)	12	3	17	0,08	44	[FLD14]
%	26	27	7	39	1	100	
Meuse, 1993-95	148	175	15	25	-	348	[FLD14]
%	42	50	<1	7	-	100	
Bretagne, 2000	65	44	5	56 (c)	-	171	[FLD05]
%	38	26	3	33	-	100	
Somme, 2001	30	10	7	94 (c)	-	141 (d)	[FLD09]
%	21	7	5	67	-	100	
South-East, 1999	168	86	52	182 (c)	-	488 (e)	[FLM38]
%	34	18	11	37	-	100	

(a) Included in “Road and networks”

(b) Average = 4600€/house

(c) Roads, networks and public buildings

(d) Damage to the environment not included: 35 M€

(e) Damage to the environment not included: 42 M€

Though based in some cases on indemnification paid by insurance companies (i.e. at lower level than real cost), they are considered to be realistic. They can be compared with *ex-ante* (thus theoretic) estimates in the Loire basin for a flood as severe as the 1856 one: economic activities amount for ~60%, damages to housing for ~25%, damages to agriculture for ~10% and damages to roads and networks for ~5% [FLP11].

Damages to the environment have been partially quantified in only two cases (Somme and South-East). In both cases, these costs mainly include damage to the rivers (banks were torn away, logjam formed, etc.).

To this regard, following elements have been observed in France [FLM35]:

- damages to housing and industry always amount for more than 50% altogether. Exceptions are rare
- large variability of the share of damages to housing, with a 1 to 4 factor
- damages to public equipment (roads, bridges, water networks...) always have a large share (though information sometimes lack to identify them among “miscellaneous” category): 37% in average (see table above).
- experience shows that knowledge varies significantly depending on the type of damages. E.g. damages to housing are very well documented, what is not the case for damages to public equipment or to the environment. It is thus very difficult to integrate them in models and to appraise properly them *ex-ante*. E.g. figures for the Loire estimate that damage to public equipment would range around 5% [FLP11] what is much lower than figures observed in other basins.

3.1.4- Factors determining damages

Several factors impact the level of damages. In broad terms, they can be gathered in 3 categories:

- **physical conditions of the flood:** water depth, water velocity, duration of flood, season, quantity of sediments carried by flood...
- **exposed capital:** land and real-estate values, value and location of personal properties and objects of comfort, protection of cables and networks...
- **human response before and during crisis:** alert, preparedness, awareness, immediate behaviour following alert (i.e. credibility given to the alert)...

Regarding physical characters of the flood, it seems that some fundamental elements are widely admitted by experts and are similar in all countries.

Insurance companies consider velocity and duration of flood as key factors (as consequences are often late and severe for buildings); so does the English methodology: these two factors are considered in calculation in order to establish priority score for projects. Yet, all experts don't pay so much attention to these factors [FLD14].

Other criteria are also used in damage functions. E.g. for shops and industry:

- water depth: < or > to 0,80 m
- duration of flood: < or > to 24h
- lead time for reaction: < or > to 48h

Combination of these 3 factors leads to 8 situations, estimated to lead to 10 to 100% damage. Damages to perishable stocks are always considered at 100%; damages to constructions are estimated at 20% of the total [cited in FLD14].

In housing, 3 key factors impact the level of damage [FLD04]:

- level of luxury. E.g. collective building with low rent 10 500 €; collective building of good status 22 500 €; bourgeois single-family dwelling with basement 30 000 €
- sensitivity to protection measures. E.g. share of furniture (often ~40%), presence of a floor allowing to evacuate equipment...
- quality of construction material. E.g. modern buildings with concrete and metal are easier to repair and dry compare to older ones (wood, masonry).

As will be detailed below, list of factors determining vulnerability of households can be very much refined.

As damage functions are very difficult to calculate given the large number of factors, typologies are often established with high numbers of categories in order to reduce the very high dispersion of observed values.

Although it is widely admitted that the principal determinant of damages is water depth, example on the Dutch part of the Meuse in 1993 shows that this link between water depth and damages is not necessarily fully linear (see figure below). Yet, representativeness of financial figures for top classes of water depth is discussed.

Damages to furniture and houses compared to water depth

Class of water depth (m)	Occurred damage (Fl)
0 - 0.2	9988.76
0.2 - 0.4	14 598.04
0.4 - 0.6	17 515.38
0.6 - 0.8	20 438.32
0.8 - 1	20 249.82
1 - 1.5	20 352.86
1.5 - 2	12 941.12
2 - 2.5	14 754.78
2.5 - 3	18 366.19

Source: [FLM13]

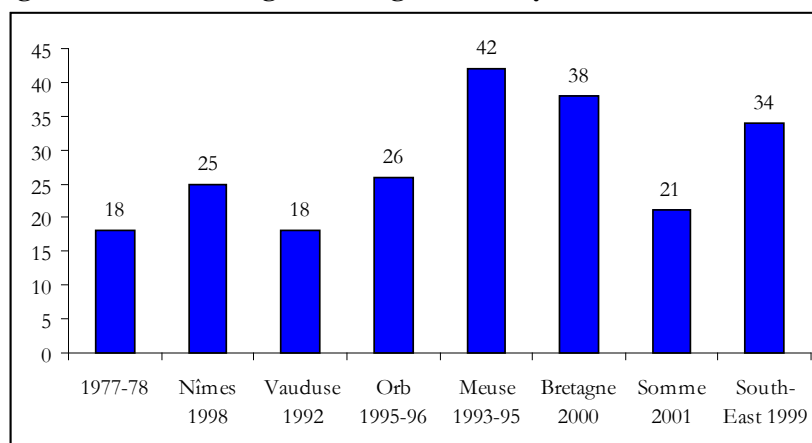
Correlation seems more likely between relative cost of damage compared to overall value of housing (coefficient of damage) as real-estate and personal properties values are generally linked by the owner's standard of life [FLD14].

The above figure also brings to light that it is necessary to consider water depth very accurately, in particular up to 1 metre. Indeed, the potential level of damage will vary very much when the depth of water remains limited, in particular as individual protection measures may make huge differences in terms of damages in such circumstances. Therefore, it is proposed to aim at errors of less than ± 5 cm in the estimation of the depth of flooding in the individual property [FLP26]. Besides, the most frequent floods are shallow floods and it is the losses from the frequent floods which contribute most to the estimation of the benefits of flood alleviation.

3.2- Damages to housing

Damages to housing generally represent a large share of all damages; yet this share may vary to a large extent. This appears clearly when comparing eight recent flood events in France (see figure).

Share of damages to houses among all damages cause by recent flood events in France (%)



Sources: [FLD14][FLD05][FLD09][FLM38]

No clear evidence appears for higher damages in case of flash floods, though such floods are generally very violent and destructive: the highest two figures refer to fluvial floods (Meuse and Bretagne).

Here, the share of damages to housing among all damages varies by a factor 2.3 and damages to houses represent in average 28% of all damages. Yet, it is reported that this share may even increase by a factor 4 [FLM35]. Damages to housing represented 63% of all damages reported following flood in the District of Bern in 1999 [FLD17].

Vulnerability of households to flood depends on several factors. A definition has been proposed that clearly shows the complexity of this issue, as 5 variables are identified, each depending on various parameters [FLP26]:

- social and economic
- property and infrastructures
- flood characteristics
- warning
- response

Several parameters are proposed to refine this interrelation among the 5 variables, such as the age profile and the income of the household, the susceptibility of building contents and fabrics to damage, the number of storeys, the sediment concentration and size; the warning time provided, the amount and quality of response...

Transferability of information on damages to housing (e.g. damage functions) seems misleading as social and cultural characters have major impact in this sector. As damage functions are built on typologies of housing (material, architecture, organisation of dwellings...) and of domestic equipment, reference costs appear very “national” [FLD26]. However, methodologies applied (analysis and estimation of impacts, organisation of data collection and management...) are judged transferable.

When considering damages to housing, it is necessary to separate damages to buildings from damages to mobile assets (furniture, appliances...).

3.2.1- Buildings

Several intrinsic factors have influence on the damage to buildings: age, quality of materials and of furnishing...

Apart from the characters of the flood itself, one key external factor determining the level of damages is the time needed to restore services [FLP26]:

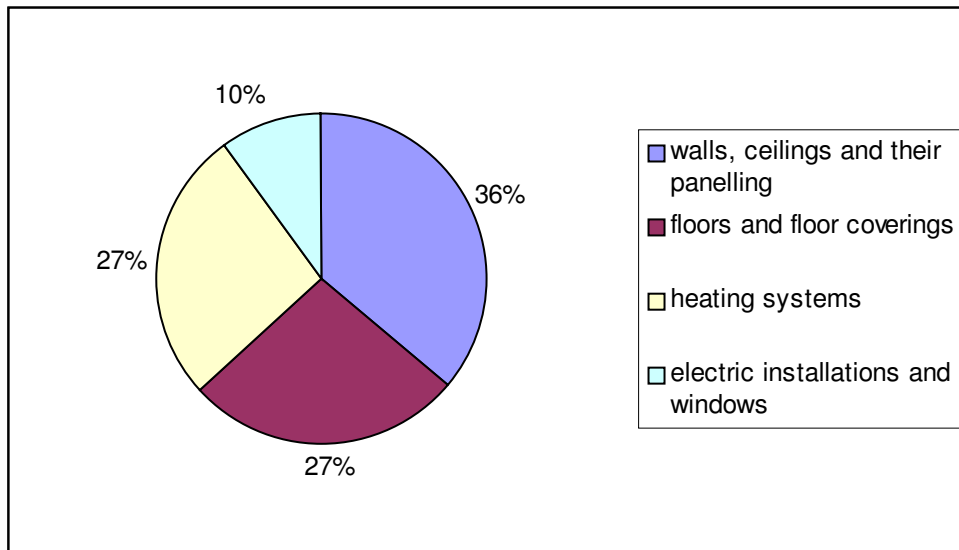
- electricity and energy in general are necessary to dry flooded items and to heat the house;
- wastewater collection is also essential: as long as it is not ensured, house can't be inhabited.

Restoration of such services also determines lead time for taking clean-up measures.

Altogether, these factors contribute to the level of damage to building.

In practice, most damaged parts of the buildings are walls, ceilings and their panelling (see following figure).

Respective shares of damages to buildings



Source: [FLM12]

Following table provides examples of estimated costs of damages to houses, based on several sources.

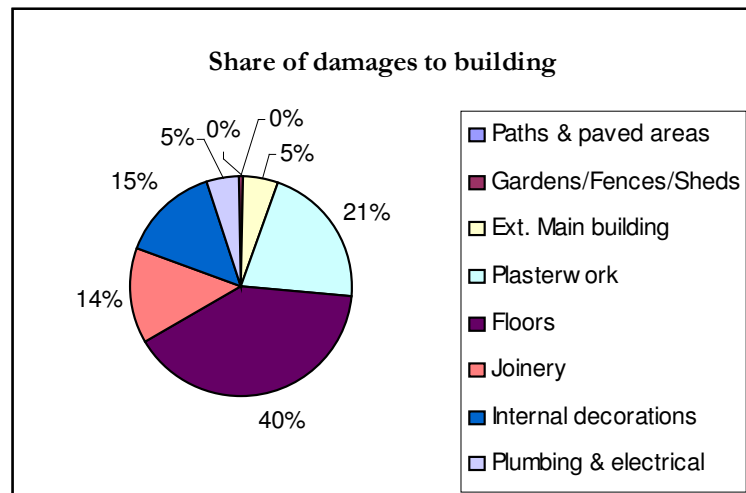
Figures for the Rhine basin clearly show the connection between the potential level of damages and the wealthness. However, these figures are calculated in broad terms, using statistical information.

English figures are the most detailed ones, as they take account of several factors: characters of the house, water depth, duration of the flood. Besides they are based on post event valuation study, carried out after autumn 2000 flooding, that affected 10 000 properties. Reliability seems very good, though transferability of such data to different contexts may be discussed [FLP26][FLD26].

Some examples of estimated direct costs of damages to houses

AREA	DESCRIPTION	COSTS	SOURCE OF DATA / COMMENTS	BIBLIO
Rhine / Baden-Wurttemberg	Patrimonial value of housing sectors	268€/m ²	Determination of mean values for each category of use: housing, industry... Detailed statistical data available in German Länder; adaptation to other countries with specific factors. Material damage are determined with a damage function. This information is crossed with gross typology of uses of land, then turned into cost /m ² of land / type of use	FLD03
Rhine / Hesse		231€/m ²		
Rhine / Rhineland-Palatinate		181€/m ²		
Rhine / Rhine-Westphalia		231€/m ²		
Rhine / Switzerland		275€/m ²		
Rhine / France		217€/m ²		
Rhine / Netherlands		252€/m ²		
UK	Total damage to building fabric i.e. damage / m ² of building	32 360 € / house 417 €	Ex-post surveys Depth above upper surface of ground floor: 0,3m Flood duration > 12 hours Figures for a pre 1919 detached property	FLD12
Loire / France	Collective social housing	10 000€ / dwelling	Experts' judgements (insurance companies)	FLD04
	Luxurious individual house	43 000€ / house	Level of flood is considered not fundamental for estimates in terms of order of height as damages occur above 20cm.	

Costs regarding the English case can be detailed as follows. This balance applies under conditions mentioned above (pre 1919 detached property...).



Source: [FLD12]

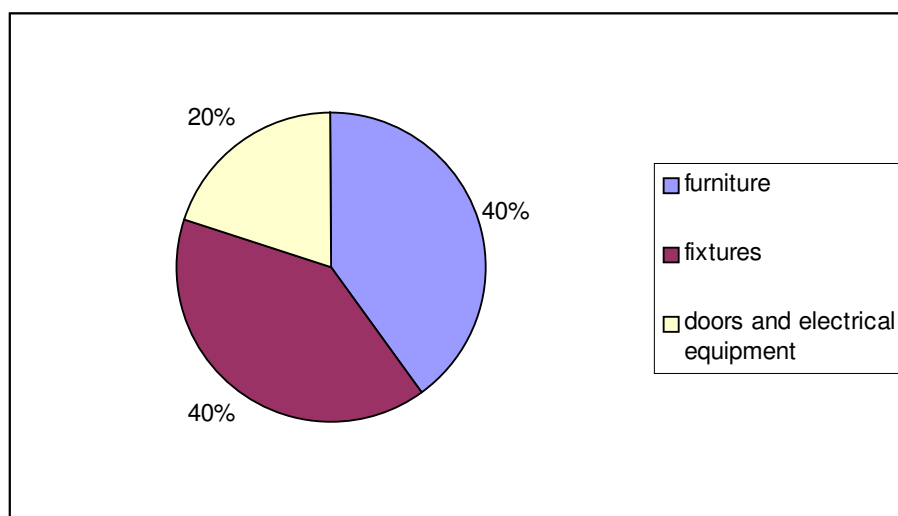
3.2.2- Mobile assets

The situation of damages to domestic equipment is very specific. Indeed, the level of damages is linked to several factors that may be combined in several ways, in particular:

- the wealth of the households, as it determines the quantity and the value of items in the house
- the characters of the flood itself: depth and duration in particular but also velocity of the flow
- the individual measures taken before the flood comes, either regarding the conception of the house (e.g. groundfloor kept for garage only, electric cables located above a certain level...) or the emergency measures taken following warning (e.g. removal of all goods up to first floor)

Therefore, amounts may vary in a large proportion. Yet, based on several studies carried out in Rhine countries, ICPR proposed an average share of damages to equipment (figure below).

Damages to equipment



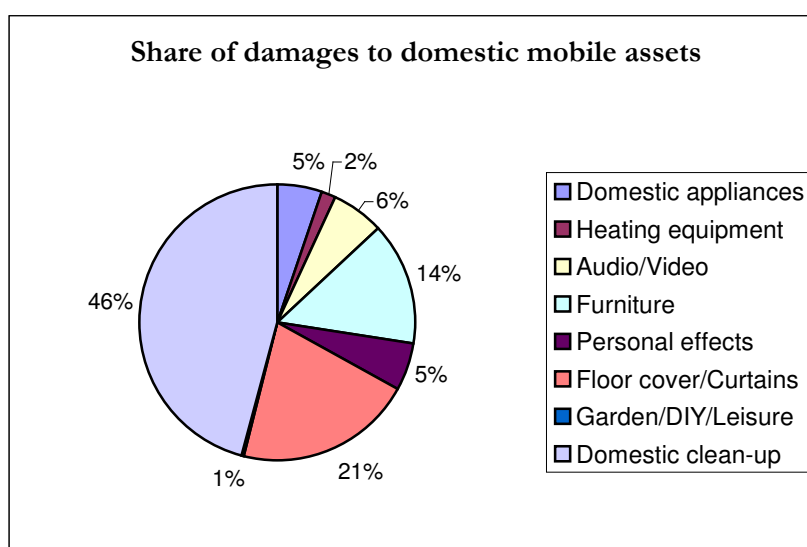
Source: [FLM12]

Some examples of estimated direct costs of damages to domestic mobile assets

AREA	DESCRIPTION	COST	SOURCE OF DATA / COMMENTS	BIBLIO
Rhine / Baden-Wurttemberg	Patrimonial value of housing sectors	54€/m ²	Determination of mean values for each category of use: housing, industry... Detailed statistical data available in German Länder; adaptation to other countries with specific factors. Material damage are determined with a damage function. This information is crossed with gross typology of uses of land, then turned into cost /m ² of land / type of use	FLD03
Rhine / Hesse		51€/m ²		
Rhine / Rhineland-Palatinate		41€/m ²		
Rhine / Rhine-Westphalia		58€/m ²		
Rhine / Switzerland		65€/m ²		
Rhine / France		51€/m ²		
Rhine / Netherlands		59€/m ²		
UK	Total damage to domestic equipment per house	Damages: 18 110 € Clean-up: 15 200 €	Ex-post surveys Depth above upper surface of ground floor: 0,3m Flood duration > 12 hours Figures for a pre 1919 detached property Clean-up costs amount for 45% of all costs. (1)	FLD12
District of Bern / Switzerland	Furniture	7 400 €	Average cost of indirect damages per claim following 1999 flood	FLD17
	Cleaning-up	910 €		

(1) Clean-up costs are considered as *direct* costs in the UK, though this is generally not the case in literature.

Costs regarding the English case can be detailed as follows. This balance applies under conditions mentioned above (pre 1919 detached property...).



Source: [FLD12]

The amount of damages to mobile domestic assets can be significantly reduced by individual non-structural measures may be implemented at individual level, by flood proofing of constructions, flood preparedness, etc. In practice, people often aren't informed on what types of measures they may implement (particularly where flood are unusual) and either take no measures (thus experience severe damages) or take inadequate measures (thus also experience significant damages) [FDL27]. Yet, benefits of such measures are demonstrated [FLM12]:

- damages may be reduced by 50 – 75% if buildings are sealed and by 10 – 30% if interior fittings are not sensitive to the impact of water.
- protected oil heating may reduce damages to buildings by 50-65%

- removing or moving furniture from or in housing estate may reduce damage to furniture and equipment by 20 to 80 %. Experts consider that the warning lead time should at least cover 4 hours [FLM12] though in practice it may be short [FLD14].

3.3- Damages to economic activities

3.3.1- Infrastructure, buildings, machines

Damages to buildings, machines, infrastructure, stocks... are direct damages: they are damaged or destroyed by the flood itself. Four main factors likely to determine the level of damages are proposed [FLD04]:

- duration of the flood, with a very low threshold for goods (24h) and a proportional relation for operating loss
- water depth, though the connection damage-depth is not as obvious as it can be for residential properties
- time needed to restart networks activities (energy, water, wastewater), time for specialised companies to clean-up, dry, decontaminate industrial sites
- geographic scope of the flood (i.e. number of companies flooded at the same time), this factor being linked to the previous one

Some examples of estimated direct costs of damages to economic activities

AREA	DESCRIPTION	COST	SOURCE OF DATA / COMMENTS	BIBLIO
Rhine / Baden-Wurttemberg	Patrimonial value of industrial sectors	262€/m ²	Determination of mean values for each category of use: housing, industry... Detailed statistical data available in German Länder; adaptation to other countries with specific factors. Material damage are determined with a damage function. This information is crossed with gross typology of uses of land, then turned into cost /m ² of land / type of use	FLD03
Rhine / Hesse		258€/m ²		
Rhine / Rhineland-Palatinate		259€/m ²		
Rhine / Rhine-Westphalia		231€/m ²		
Rhine / Switzerland		287€/m ²		
Rhine / France		229€/m ²		
Rhine / Netherlands		262€/m ²		
Middle Loire / France	Average damage to "office activities"	7 600€/employee	Statistics – Experts' judgements Level of flood > 1m – Duration >48h	FLD04
	Average damage to intermediate goods industry	430 000€/employee		

Most vulnerable goods are production means (machines...), thus activities directly linked to production face the highest costs of direct damages.

We can see that the basis for estimates is not the same in both cases: either per m² or per employee. In both cases, the choice of the basis is closely linked to the availability of data and to the structure of databases, as statistics are widely used. As for other activities, detailed typology was established in the Loire basin: 53 activities are identified in order to calculate damage functions.

Transferability of information on damages to economic activities (e.g. damage functions) seems possible as social and cultural characters have limited impact in this sector: for a similar industrial activity, development and organisation of production means are rather similar from one industrialised country to the other [FLD26].

It is acknowledged that impact of flood on economic activities is not well documented, in particular compare to damages to housing [FLP26]. Besides, it appears in literature that economic activities are *de facto* associated to production activities, but that the situation of small businesses, shops, etc. is not investigated. Yet, their vulnerability may be very high too (higher?) and their human and financial capacities to cope with the flood and to recover from are quite limited compared to large companies' (clean-up, replacement of the stocks, etc.). Two examples may be given:

- there is evidence that supermarkets recover in a much shorter time than small independent shops despite complete loss of stocks [FLD14]
- in the 1999 flood in the district of Bern, restaurants and hotels, often situated next to rivers, were most severely damaged: 24,4 % of the total amount of damages to “Economic Activities” concerned hotels and 20.8% concerned restaurants [FLD17].

3.3.2- Disruption of production

There may be several types of indirect costs caused by floods to economic activities:

- cleaning-up
- loss of clients and markets
- cost for moving to a safer place...

However, literature focuses on loss due to disruption of production i.e. operating loss.

Following variables are identified as determining the vulnerability of economic activities with regards indirect damages [FLP26]:

- dependence, i.e. the degree to which an activity requires a particular good as an input to function normally
- transferability, i.e. the ability of an activity to respond to a disruptive threat by overcoming dependence either by deferring the activity in time, or by relocation, or by using substitutes
- susceptibility, i.e. the probability and extent to which the physical presence of flood water will affect inputs or outputs of an activity

The dependence factor is fundamental as it includes raw material but also electricity and water (though water is less fundamental for most activities). Economic activities themselves generally have limited control on this factor and are very dependent of the capacity of other sectors to cope with the flood (crisis management) and to recover from it (e.g. power companies).

There is limited information on this aspect: post event surveys carried out in three recent severe floods show limited costs of damages in 2 cases (0,5 M€, 3500 disconnected households) and significant ones in the third one (6 M€) [FLD05][FLD09][FLM38]. It can be noted that the third case is an example of flash flood. It can be suggested that violent and powerful flash flood may be much destructive for electricity grid than fluvial flood.

Besides, it is estimated in the Loire basin that in the case of extreme flood (similar to 1856 one) 4 100 electricity transformers and 1 000 electricity towers (of which 25% in streams) would be exposed then potentially affected [FLD06].

Average values are generally used to estimate indirect damages (operating loss) [FLD14]:

- 25-30% turnover for wholesale trade and supermarkets
- 40-60% for retail trade and craft industry
- 55-60% for food service industry
- 90% for services and engineering

The following formula is proposed to estimate these damages [FLD14]

$$OL = TO/12 \times (d + r) \times Sf$$

Where:

OL = operating loss

TO = turnover

d = duration of flooding

r = restoration time in months

Sf = specific factor dependent on the type of activity:

- 0,3 for retail

- 0,5 for industry

- 0,4 for warehouses

- 0,6 for hotels and restaurants

- 0,9 for transports and services (engineering, insurance, bank)

Some examples of estimated indirect costs of damages to economic activities

AREA	DESCRIPTION	COSTS	SOURCE OF DATA / COMMENTS	BIBLIO
Rhine / Baden-Wurttemberg	Patrimonial value of industrial sectors	83€/m ²	Determination of mean values for each category of use: housing, industry... Detailed statistical data available in German Länder; adaptation to other countries with specific factors. Material damage are determined with a damage function. This information is crossed with gross typology of uses of land, then turned into cost /m ² of land / type of use	FLD03
Rhine / Hesse		80€/m ²		
Rhine / Rhineland-Palatinate		81€/m ²		
Rhine / Rhine-Westphalia		80€/m ²		
Rhine / Switzerland		96€/m ²		
Rhine / France		76€/m ²		
Rhine / Netherlands		87€/m ²		
Middle Loire / France	Average damage to banks and real estate agencies	0€/employee	Statistics – Experts' judgements Losses caused by disruption of activity	FLD04
	Average damage to activity of services to companies	76 000€/employee		
District of Bern / Switz.	Furniture	51 000€	Average cost of indirect damages per claim following 1999 flood	FLD17
	Cleaning-up	3 575 €		
	Disruption of activity	111 800 €		

Surprisingly, a “no loss” hypothesis is proposed in the Loire basin for flood affecting banks and real estate agencies. No explanation is provided to explain such figure. We can suggest two explanations:

- these are very local activities with a local market and flood is likely to affect all competing agencies in one sector at the same time. A transfer of clients to other agencies located in non-flooded areas is then unlikely;
- activity in these sectors is probably postponed rather than lost: this is widely due to the previous factor.

The size of the flooded area appears as an important factor determining the capacity of competitors from non flooded areas to supply clients before the activity is in capacity to restart. This may appear only in the mid-term thus not be considered as a flood damage, but such a factor may significantly contribute to closing down of some activities [FLD26][FLP26].

It then appears quite clearly that damages to economic activities depend very much on the crisis and post-crisis management. Though companies and businesses themselves have to be properly organised, they widely depend on the capacity of public authorities to ensure that infrastructures and services can quickly recover from the flood.

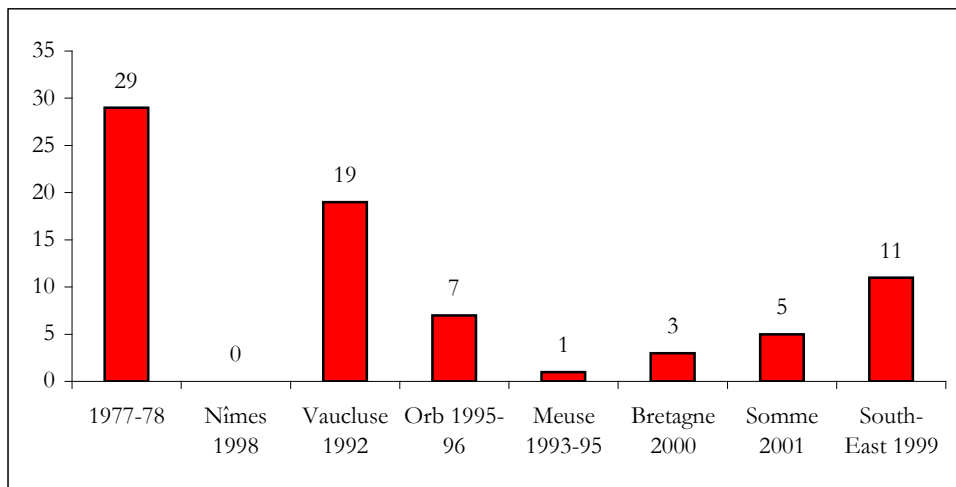
3.4- Damages to agriculture

3.4.1- Introduction

Far less data on damages caused by floods to agriculture is available, compared to residential sector for instance. Contrarily to damages to housing or to other economic activities, figures found regarding mean unitary costs of damages are only based on theoretic *ex ante* estimates.

The share of damages to agriculture depends very much on the profile of the flooded area. Following table for several recent floods in France demonstrates this wide variability (average: 9%). Only overall figures for agriculture activity are available for these events, with no detail per type of activity for instance.

Share of damages to agriculture among all damages caused by recent flood events in France (%)



Sources: [FLD14][FLD05][FLD09][FLM38]

The flood in Nîmes was urban only. The same appeared in the urban district of Bern in 1999: damages to agriculture counted for 2,6% of all damages (0,6% in the city of Bern) [FLD17].

One difficulty for providing figures is methodological: “agriculture” covers several different types of activities, which are in very different positions towards floods. E.g. there is not much in common between prairies and horticulture in greenhouses. Besides, distinction has to be made between damages to productions (crops, cattle) and damages to buildings.

Therefore, two approaches may be applied:

- either the goal is to provide general figures at large scale: “gross averages” figures may be used as the specific type of production of each sector does not make any difference then.

E.g. such estimates are proposed by ICPR to grossly assess stakes in the agriculture sector. On this basis, it is estimated that costs to agricultural sectors range between 5 € / m² (Rhineland-Palatinate) and 9 € / m² (Rhine-Westphalia). In other sectors in Switzerland, Germany, France and the Netherlands, value is 7 € / m² [FLD03].

E.g. An average estimate of overall damages in agriculture sector of the Loire-Bretagne basin (i.e. approx. the west of France) was carried out [FLE22]. As it was not possible to take account of all factors that may determine damages (type of culture, season of the flood...), it was decided to estimate minimum and maximum cost/ha: between 45 and 750 € / ha.

These estimates appear rather “small” in the French case compared to estimates applying to industrial or dense areas; yet they may locally represent a large share of all damages, when cultures with high added-value are flooded.

- either the goal is to appraise local damages: detailed estimate is then necessary. Therefore, as costs estimates are based on damage functions, it is necessary to characterise types of sectors within the agricultural sector as a whole. Extensive works have been carried out in Middle Loire on this issue, based on the establishment of very detailed typologies (up to 18 types among the horticulture sector) [FLD04]. Besides, research projects attempted to characterise factors contributing to vulnerability of agricultural activities [FLD21][FLD22]. Despite significant efforts in this sector, it seems that knowledge remains very partial as interest for this issue is recent [FLD40].

3.4.2- Damages to infrastructures and facilities

As mentioned above, gross estimates have been provided for different sectors of the Rhine (from 5 to 9 € / m²).

In the Loire basin, a specific methodology was applied to carry on estimates [FLD04].

Average costs of damages are calculated per agricultural enterprise and per level of alea.

They are obtained by a combination of following information:

- average equipment: machines, stocks, buildings
- replacement value of equipment
- damage coefficient i.e. level of alea

On this basis, estimates for buildings and equipment (for irrigation...) range between:

- <15 000 € in case of “low alea” (level of flood<1m / slow flow)
- and 183 000 € for arboriculture exploitation in case of “high alea” (level of flood>1m / high velocity of flow) and (in case).

3.4.3- Damages to crops and cattle

Once again, limited information is available. Analysis carried out in the Loire basin have led to the identification of several types for which estimates of average costs of damages have been made, both for damages to crops and to cattle. A similar methodology was established to estimate damages to crops [FLD04].

Average costs of damages are calculated per hectare, per period and per level of alea. They are obtained by a combination of following information:

- values / hectare of the production (turnover) and of specific equipment (replacement value)
- period coefficient: distinction between spring and autumn
- damage coefficient i.e. level of alea

As an example, following figures are obtained based on this methodology:

- beans culture: from 45€/ha (autumn flood) to 2000€/ha (spring flood)
- horticulture in greenhouses in urban area: up to 7 100€/ha (autumn flood)
- corn culture when flood from 600 €/ha (autumn flood) to 1700€/ha (spring flood)

Similar data is available for several types of cultures: wheat, vegetable, market gardening, etc.

In order to estimate the costs of damages to cattle, refined approaches have been developed, considering different circumstances: e.g. farmers alerted or not. In the case of the most sensitive agricultural area (*Val d’Authion*), possibilities of alert seems very theoretic as flood risk comes mainly from possible breaches in dykes and levees. Other hypothesis consider partial evacuation of cattle right at the beginning of the flood the evacuation of the rest of the animals between 1 or 3 days later. Detailed assessment methodology is available [FLD04].

Following figures of cost / animal can be proposed:

- for livestock, damages could range between 150 € (young bovine / low alea) and 2 600 € (dairy cow / high alea);
- for fowl, damages could range between 2,30 € (“industrial” chicken/low alea) and 26 € (turkey/high alea).

As these figures only refer to indirect costs of damages, overall estimates shall include also direct costs to buildings as estimated above.

3.5- Damages to public buildings

This issue is poorly documented, for different reasons:

- focus is put on damages to housing and to economic activities: survey of the literature demonstrates this clearly. Thus, other types of damages are not well known. In the case of damages to buildings there is little more than simply general *ex post* figures;
- in many cases, these damages are not insured or very partially only. Therefore, there exist almost no figures on the costs, apart from post-crisis first estimates, which are not always very accurate (either too high or too low) [FLD26].
- damages to public buildings are often gathered into a “miscellaneous” category, together with damages to networks and even rescue and aid costs.

Given this lack of information, no distinction is found in literature between costs of damages to buildings themselves and to furniture and other mobile assets i.e. between direct and indirect damages. Yet, as some services provided by public organisations play a key role in time of flood (crisis, post-crisis, medium term assistance...), disruption of activity or loss of administrative documents in public buildings may lead to further damages.

As an example, following cases of French public buildings being flooded, sometimes with very high damages) have been reported:

- in the South-East of France: fire and police stations. One has been rebuilt in flood prone area and was thus flooded again a few years later [FLM38]
- in Bretagne: control centre involved in flood crisis management, announcement centre, rescue centres, hospitals [FLD05]

Once again, research carried out in the Loire basin provides some elements [FLD04] but their transferability to other countries is doubtful at first sight. Indeed, the level of equipment and the types of buildings may widely vary, depending very much on local organisation (density of public services, supply of equivalent services according to several organisation patterns, etc.).

Yet, given the knowledge gap in this sector, it is interesting to consider these figures.

Research carried out in the Middle Loire basin demonstrated that access to information was very difficult given the little information insurance companies could provide²³. A survey was launched with questionnaires sent to organisations managing public buildings in recently flooded areas.

The first finding is very interesting and would certainly require further investigations: surprisingly, costs of damages so collected show little correlation with usual parameters (e.g. water depth). Thus figures calculated as average costs are not associated to level of risk nor to type of building.

Figures were obtained by calculations based on probability.

²³ A synthetic approach was implemented there, based on experts’ judgement. This is why insurance companies played a significant role in appraisal in this basin.

On this basis, average costs range between 15000€ / equipment used for outdoor recreational activities and 200 000 € / equipment for fairground.

In the District of Bern, damages to public buildings accounted for 12% of damages caused by the 1999 flood [FLD17].

It is also suggested that damages to flood protection works may account for up to 30% of all damages [FLD03.]

3.6- Damages to networks

Statement made for public buildings is relevant for damages to networks: information is clearly lacking. Besides, when ex-post figures are provided, several factors reduce the relevance of comparisons:

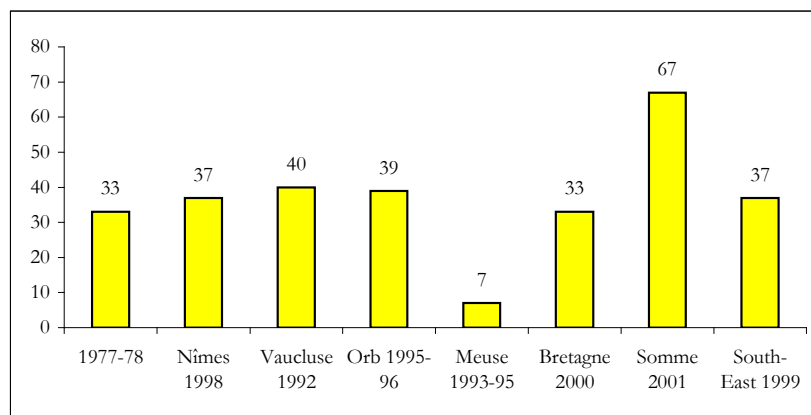
- it is not clear whether they refer to the same types of damages: some only refer to roads and bridges, other include transportation infrastructure or water networks...
- scales for assessment are often distinct: e.g. flash floods reported in South-East of France are often very local and may occur simultaneously in several distinct places. Yet, as electricity grids are organised at regional level only regional data on damages may be provided.
- information is often not available or not reported because infrastructure are not sometimes not insured, in particular when they belong to public authorities
- in the case of damages to roads, replacement works often include upgrading of unflooded elements also. It is not possible to separate costs generated by the flood itself.

Thus, all figures on this aspect have to be taken very cautiously given the uncertainty of sources of data.

Given these limits, it is then difficult to appraise such damages.

Yet, based on figures from some recent floods in France, it seems that this type of damages may represent a (very) significant share of damages (see figure): 37% in average.

Share of damages to networks among all damages caused by recent flood events in France (%)



Sources: [FLD14][FLD05][FLD09][FLM38]

The following two comments can be made:

- as mentioned above definition (then contents) of “Roads and networks” category is not homogeneous: includes or not damages to public buildings; cost of rescue...
- in average, costs of damages to “roads and networks” are higher in case of flash floods. Yet, the highest cost was reached in the Somme flood, which was a plain flood but that lasted for months. This is certainly the explanation for such a high cost (direct damages, disruption of activity for trains...)

Based on surveys, the *Equipe Loire* proposed some figures regarding average cost / km of flooded road (but not necessarily ravelled): between 6000 and 53000€ / km depending on flood parameters (water depth, velocity of flow) [FLD04].

Besides specific surveys in the Loire basin also targeted water and wastewater utilities, which are often not separated from public buildings or networks at large or not even appraised. It seems that direct costs are rather limited: from 15000 € for small utilities up to 100000 € (wastewater treatment plant) or 150000 € (drinking water plant) in large utilities [FLD04].

Costs of damages to this type of utilities are likely to vary widely. E.g. wastewater treatment plant may be significantly affected depending on the volume of rainwater collected and also on the quality of this water (first flow is often highly polluted).

Yet, as most infrastructures are underground, they may be less affected in lost cases. However, disfunctioning may cause damages to connected buildings (houses, businesses, factories...) because of wastewater overflow. This may cause direct damages to affected buildings and also indirect damages to people esp. foul smell [FLP26].

Some figures are provided in annexes as part of compilation of costs of damages in some recent events (France, Switzerland).

3.7- Intangible damages

The question of the appraisal of intangible damages is difficult by nature: how to quantify them? in what terms: monetary, other? how to take them into account into economic analysis of efficiency (CBAs or others)? etc.

Though complex, this issue is fundamental: priced losses are often not those which are regarded as most important by flood victims [FLP26][FLD12][FLD14][FLD27][FLD28][FLD29].

Intangible damages include damage to people (casualties, health, well-being...) but also damages to the environment. In the latter case, information is highly scarce.

3.7.1- Casualties

As stated in the introduction of the present report, flood cause significant human damages at European scale: between 2000 and 2004, 185 people died and 171 were injured by floods in EU 15.

In many cases, number of deaths caused by a single flood was very high:

- 7 in Austria (Aug. 2002)
- 9 in France (Dec 2003)
- 24 in France (Sept. 2002)
- 7 in Germany (Jan 2003)
- 27 in Germany (Aug. 2002)
- 11 in Greece (Jan. 2001)
- 29 in Italy (Oct. 2000)
- 16 in Italy (Sept. 2000)
- 16 in Spain (June 2000)

Indeed, although the overall risk of death in an area at flood risk is generally low, it may significantly increase when either the flood velocity is high or the depth of water is great. In such cases, the risk to

life often doesn't satisfy the criteria of tolerable or acceptable risk normally applied to human-induced hazards such as nuclear power stations or chemical plants [FLP26].

Experience shows that behaviour in case of flood is determining regarding the risk of death. Several behaviours and attitudes create tremendous risk [FLM12]:

- senior or handicapped citizens should not stay in parts of the building lying below the maximum flood depth: southern France 1999, 10 casualties
- the use of rooms without any possibility of escaping to higher floors: Brig CH 1993, 2 casualties
- the use of basements and underground garages: Boll, CH 1987, 1 casualty
- the use of elevators: Augsburg D 1999, divers rescued 1 person
- to camp in the course of flood water discharge: Savoie 1987, 23 casualties

In Switzerland, misconduct played an important role in 40 % of the 67 casualties due to floods registered between 1972 and 2001.

The use of cars on flooded roads is one of the main causes of death: Switzerland, 1987, 3 casualties, southern France, 1999, 10 out of 24 casualties. It is estimated that staying in a vehicle may turn out to be mortal, as buoyancy is underestimated and a car may already be carried away at a flood depth of 50 cm [FLM12].

The following table details circumstances of death of 35 people (South-East of France, Nov. 1999).

Location of death	Home	In car	Out of car (but connected to the use of car)	Other	Total
Cause of death					
Drowning	7	7	8	4	26
Malaise	1	1	0	2	4
Shock	1	0	0	0	1
Mudflow	4	0	0	0	4
Total	13	8	8	6	35

Source: [FLM38]

All these figures demonstrate very clearly that knowledge and awareness of risks is essential. This shall be taken into account in designing information policies: this is an unexpensive and quite simple way to reduce the risk of casualties.

3.7.2- Human health and well-being

In order to integrate intangible damages and to take measures likely to reduce them, main concerns need to be identified. Surveys and focus groups provide very useful information to this regard [FLD25][FLD27][FLD28][FLD29].

Focus groups and enquiries in UK showed that the impact reported as having the greatest severity was the problem of getting the house back to normal again [FLP26]. Next to the duration of the disruption, stress received during the flood entered into the assessment of the severity of this disruption. Other factors contributing to the perceived degree of damage were reported, such as:

- destruction of furniture, decoration or garden self-made over the years;
- wealth of the household (including ongoing loans...) i.e. financial capacity to recover after the flood

- physical troubles, that seem to be closely linked to the degree of stress experienced during the flood
- social support received from friends and from the community at large

Stress is cited as one of the most significant health effect of the flood. Besides, it contributes to the severity of other troubles. People could identify it as they didn't suffer from psychological troubles *before* the flood. Afterwards, they fell anxiety, they lost sense of security in their homes, etc. Studies have shown that between 15 and 20% of persons studied after natural disasters were reported to have symptoms of Post Traumatic Stress Disorder (PTSD). Then rainfalls and storms may generate intense stress later on. While physical health troubles have disappeared 1 year after flood, psychological ones remained [FLD25]. Significance of such effects, though not quantified, demonstrate the importance of well-prepared emergency plans, post-crisis measures, etc. They are not only necessary because they reduce quantifiable damages.

Surveys also show loss of confidence in authorities: they have not "avoided" flood, not warned early enough, not maintained dykes and other works, not found immediate solutions, not helped as much as was needed following crisis, etc.

Psychological impact of the destruction of natural heritage also contributes to the general feeling of personal damage and well-being.

As for casualties, it appears that improved preparedness, awareness, good and reliable information, early warning and other such non-structural measures have direct impact on damages and on acceptability, thus may significantly reduce intangible human damages such as anxiety, impact on health, etc. E.g. loss of memorabilia (photographs, personal items, etc.) that account very much in the perception of the gravity of flood (one of the key factors [FLD25]) can be highly reduced if people have time to move them away from flooded places (upstairs...). The key is then early and reliable information and awareness (people have to integrate the fact that they are exposed) [FLM36].

In many cases, people know that their house is located in flood prone area but don't believe it. E.g. in Bretagne, there was no severe flood between 1936 and 1995. So people didn't pay attention to the risk [FLD27].

Culture of risk is certainly essential: comparison of behaviours in the case of floods in the Saône and in Bretagne in 2001 show that where flood is common (Saône), it is not much associated to danger and often taken as fate. Thus trauma is significantly reduced [FLD27]. Similarly, it is demonstrated that knowledge of the imminence of the flood reduces stress [FLP26].

Yet, in terms of policy making issues associated with risk to life and serious injury need to be considered carefully in flood events. There are readily available comparable tables for value of life or physical injury (e.g. in relation to road accidents) but it is doubtful they can routinely be applied to flood situations because of the difficulty of assigning reasonable levels of risk in the with and without project situation [FLD12].

Although information on damages to human life, health and well-being appears quite limited compared to information on housing for instance, growing attention is paid to it as economic analyses carried out to design flood policies include more and more socio-economic aspects. This is the case with the Multi-coloured manual in UK that includes social dimension in pre-decision studies [FLD12]. This is also true in the Netherlands and in Germany where cost-benefit analyses open up to these aspects.

As a consequence, research develops in order to fuel these approaches.

As an example, in the UK, a national study on 'The appraisal of human related intangible impacts of flooding' has been carried out in 2004. The research aims to raise the profile and understanding of the impact of flooding on people in terms of health and stress, and considers how this can be incorporated routinely into economic appraisals of flood risk management studies. The study concluded, on the basis of a very detailed survey of over 1500 households, approximately two-thirds of whom had recent

experience of flooding, that the value of avoiding the stress and health effects related to flooding are in the order of 300€ per property per year [FLD41].

3.7.3- Environment

Damages to the environment in case of flood appear, at least as can be judged from the collected literature, to be almost ignored.

Indeed, we find hardly any figure on this issue, apart from rough estimates of the damages caused by given floods, based on *ex-post* surveys, or from qualitative information. Besides, no detail is available as for the type of damages caused nor on the scope of damages not taken into account:

- quantified information: estimates for costs of damages to the Somme channel (F) reach 35 M€, of which 2 M€ were emergency expenses (pumping, repairing of dykes...). As part of post-crisis measures, short-term expenses for emergency works (studies, temporary reinforcement of dykes, ditch-cleaning, restoration of small works...) amounted for 4 M€ [FLD09]. All these measures targeted the riverbed, the channel and the surrounding natural environment.
- descriptive information: in South-East of France, thousands of trees lifted and transported by the current, waste disposal sites flooded, gold mine flooded; break of a settling basin containing sand contaminated with arsenic, obsolete industrial zones flooded; drums taken by the current... [FLM38]. In Bretagne (F), erosion (lots of uncovered soils in winter): sediments in rivers + wash-off of soils, local pollution (fuel tanks...) [FLD05]

One major impact to the environment caused by floods is the leakage of harmful substances: oil, fuel, chemicals... If water residence time is prolonged, leaking heating oil doubles to triples the damage extent. In the case of the flooding of Kelheim (Germany, 1999), about 70 % of the total damage to constructions resulted from leaking oil [FLM12].

Leaking oil increased the extent of damage, as oil may also adhere to parts of the building resistant to water, such as tiles and thus cause vast need for remedial work.

At individual scale, a flood-proof equipment of the oil tank or choosing a gas heating instead of an oil heating may reduce subsequent damage by 50 % or more. Yet, in Basel (CH), building insurance companies and authorities in charge of civil defence offered people living in the at risk areas to secure oil tanks free of charge. Hardly anybody accepted the first offer [FLM12].

In industrial sector, stocking outside the flood plain reduces the extent of damage by 100 %. Measures aimed at elevation and flood-proof stocking attain an effectiveness of 50 % to 75 %.

Part 4- Identification of measures and associated costs and benefits

4.1- Introduction

4.1.1- Identification of the measures

As discussed in part 2, several different types of measures can be implemented as part of a flood policy; to this regard, the European core group on flood protection of water directors has proposed best practices [FLM03]. Yet, depending on the aspect considered, action plans on floods may be judged very similar or very specific.

As far as contents of action plans are concerned, they all are specific as they are closely linked to a local context. Yet, a particular mention has to be made regarding action plans for the Rhine and the Meuse and for their tributaries (Moselle-Sarre [FLM63b], Nahe [FLM50]...) as they were elaborated in a specific context.

Indeed, in 1993 and 1995, severe floods occurred in both basins. As often in such a case²⁴, this led to vigorous political reaction: Ministries for the environment of riparian states demanded for measures reducing risk of damages for the future to be taken as soon as possible (Ministries declaration in Arles (F), Feb. 4th 1995). On this basis, dedicated institutions (International commissions for the protection of the Rhine, of the Meuse, of Moselle-Sarre...) started working on the elaboration of action plans. Given the close co-operation among experts and working groups and the involvement of the same authorities, plans were built on a comparable pattern. In the case of the Rhine, plans for the main river and for tributaries are even based on the same model.

Compared to these cases, plans elaborated in France are very heterogeneous: there is no official nor informal pattern, and documents are prepared in several different ways. Besides, basins considered are in most cases quite small and are only located in one country. These factors allow a greater diversity of measures. E.g. at ICPR scale it is not possible to over-detail measures that shall be taken, as the action plan plays as a guidance that has to fit in several different national contexts.

However, as far as the context in which action plans were elaborated, plans are very similar. Indeed, in most cases, they have been elaborated following severe floods as social demand for (very) firm political reaction is very high in such periods. This statement is right for the wide majority of plans we have gathered: Rhine [FLM09], Vidourle [FLM36], Meuse [FLM60], Jucar [FLM41], Nahe [FLM50], Oise-Aisne [FLM37]...

To this regard, the case of the Loire is quite specific: no severe flood has occurred for a very long time and concern for floods is *de facto* rather theoretic. At first sight, this could be considered as a very favourable context: there is no external pressure so it leaves time for in-depth analyses, studies, concertation, etc. Ultimately, this may allow a very well-informed and unpassionate decision-making process. This hypothesis is only half right in the Loire basin: several studies have been carried out, hydraulic knowledge of the river is very good, etc. This led to the preparation of a well-argued strategy issued 1999 [FLP11]. Yet, on the other hand, no political decision has been made on this basis: what is commonly called the “strategy for the Middle Loire” is in fact only a *proposal* for a strategy. This can certainly be explained: flood issue is not very high on the local political agenda, the implementation of the proposed strategy would cost at least 100 M€²⁵, there is no social pressure, etc.

²⁴ Several other action plans collected were elaborated right after severe floods occurred. E.g. Vidourle [FLM36], Jucar [FLM41], Oise-Aisne [FLM37].

²⁵ And up to 600 M€ for a full implementation ensuring a good level of safety for floods with ~200-year return period and 6000 M€ of damage potential

Plans are also similar as they are all elaborated under the auspices of a co-ordinating authority: ICPR in the Rhine, ICPMS for Moselle-Sarre, *Syndicat Mixte Interdépartemental d'aménagement et de mise en valeur du Vidourle et de ses Affluents* for the Vidourle, *Equipe pluridisciplinaire Loire...*

This co-ordination is absolutely necessary as in most countries, several public authorities are involved in flood policies to various extents: central government and decentralised services, Länder in Germany, water boards in the Netherlands, municipalities in most countries, etc.

In the French part of the Meuse a specific body (“EPAMA”) was created in 1996 in order to ensure this co-ordination, whereas in the Rhône basin the lack of such authority was pointed out as an aggravating factor following 1993, 1994 and 2003 floods [FLM29].

Therefore, in order to consider several action plans on a homogeneous way, we have established a typology of measures for the purpose of the project. The question of sorting flood alleviation measures is very discussed: one can find many different classifications and typologies in literature. For example, the Commission Communication on Flood Risk Management [FLP03] distinguishes between flood prevention and flood protection, where protection measures would include both structural and non-structural measures. This distinction between structural and non-structural measures is also adhered to by the European Environment Agency in its 2001 report on sustainable water use in Europe. However, the non-structural protection measures listed by the EEA are largely the same as what the Commission refers to as prevention.

Eight action plans have been considered in detail as part of the project: as already mentioned, special attention was paid to the basins of the Rhine, of the Loire and of the Vidourle (flash flood). Besides, five other actions plans were analysed: the Meuse, the Moselle-Sarre, the Nahe, the Oise-Aisne and the Saône. The following table provides an overview of the measures formally included in these action plans, on the basis of the typology established for the project and against which all plans are considered. Classification may thus not be the same as the one chosen by basin authorities. E.g. public awareness raising is considered as an operational objective of the Rhine action plan but the associated measure is the establishment of risk maps. It is thus referred to as such in the table and the “awareness raising” box is not ticked.

Measures formally contained in selected action plans on floods

Types of measures	Measures	Rhine	Loire	Vidourle	Meuse	Moselle	Oise	Saône
Information	Flood risk mapping and communication	X			X	X		
	Flood forecasting and early warning systems	X	X	X	X	X	X	X
	Public awareness on best practices		X	X	X		X	X
	Establishment of an emergency plan		X	X				
Prevention	Limit the use of floodplains	X	X		X		X	
	Increasing retention capability of soils	X			X	X	X	
	Increasing retention capability of floodplains and wetlands	X			X	X	X	X
Protection	Measures to reduce peak run-off		X	X	X		X	X
	Reduce level of flooding for given run-off	X	X	X	X		X	X
	Measures reducing impact of flooding	X	X	X	X	X		X
Emergency	Implementation of emergency plans		X					

Sources: [FLM09], [FLP11], [FLM36], [FLM60], [FLM63b], [FLM37], [FLM48]

At first sight, several comments can be made regarding this table:

- actions plans do not provide exhaustive overview of actions actually carried out in each basin. E.g. though no action on “public awareness raising” is formally included in the Rhine action plan, it is important to indicate that one of the best documents on this aspect was published by ICPR [FLM12]. Moreover, in all basins, other policies may contribute to the protection against floods: agriculture, environmental, land planning... Despite this “bias”, it is interesting to compare action plans, as they are the most refined documents presenting public policies on floods.
- management of the crisis is hardly included in plans, be it considered as preparation of emergency plan or as the design of specific measures to be taken in the post-crisis period. This may be surprising as it is clearly demonstrated that such measures have direct effect on the level of damages. One explanation is certainly that such measures are considered as external to flood policy, and rather as under the responsibility of civil protection and security services. Though the organisation of emergency relief and of first aid measures belong to such services, it is clear that post-crisis measures are much more than aid to flooded people (evacuation, pumping,...).
- French action plans don’t include flood risk mapping. One explanation may be that in most cases this is already done or ongoing as part of national policy. Besides, as initiative for this belongs to the state (via local services), institutions involved in flood management have no direct impact on this aspect thus don’t include it in the plan. This is different for the Rhine, the Meuse and the Moselle, due to the international context: these plans have to take account of various national situations
- all plans but one (Vidourle) combine all *types* of measures: information, prevention and protection.

4.1.2- Costs of planned and implemented measures

All plans indicate costs for the measures, and overall implementation costs may reach very high amounts, such as:

- 12 300 M€ for the Rhine basin between 1998 and 2020
- up to 600 M€ for the Middle Loire basin (no real period indicated)
- 30 M€ between 2003 and 2007 for the small Vidourle basin (850 km²)
- 500 M€ for the Moselle-Sarre basin between 1998 and 2020²⁶

In practice, information found in action plans about the costs of the measures is very heterogeneous:

- in most cases costs refer only to investment costs: works to be built, costs of studies for the elaboration of hydraulic models, upgrading of forecasting systems (switch to automatic stations...), etc.

It is considered that figures indicated cannot be transferred from one place to another for comparisons, for several reasons: they are only estimates, they apply to different contexts (and even to different countries), they often refer to high costs (millions euros) and are frequently rounded off , etc. So comparing the costs of reservoirs as stated in 2 action plans would be meaningless and certainly misleading;

- operation and maintenance costs are almost never mentioned: in the case of important works in particular (dams, reservoirs, dykes...) it is well-known that operation costs represent a significant expense on a yearly basis. In the case of the Loire strategy, it amounts for around

²⁶ An overview of the action plans for the Rhine and the Loire and for the Vidourle is provided in parts 1.1.3 and 1.1.4 respectively; detailed costs of the measures included in all action plans are provided in the annexes.

1% of the investment costs, ie. 5 to 6,5 M€ [FLP11]. This percentage appears reasonable compared to the cost of the recommended measures; yet in the Loire it is 100% more than what was actually spent each for maintenance in 1999 in the basin. Although a 1% variation of overall estimates provided in most action plans is unlikely to change political decisions given the high degree of uncertainty esp. regarding long-term works, it seems important to indicate this type of figures to decision-makers and to the public.

For instance, operation of one reservoir on the Loire (Villerest, 120 Mm³) requires around 100 flowmeters, gauging stations, etc. upstream that are maintained and checked 24 hours a day. This represents 12 full-time jobs. Experience shows that it is very difficult to ensure such a financial effort in the long term. Thus, even if the amount may be negligible compared to investment costs, it would be useful to mention it in the action plan, what is rarely the case [FLP17].

- indirect costs are generally not taken into account: almost no information is available regarding indirect costs, such as administrative costs linked to the implementation of measures. Yet, this type of costs may be high in the case of non-structural measures, in particular for the extension of floodplains (long administrative procedures) but also for extensification of agriculture in order to limit the use of floodplains, information measures, early warning systems, etc.

In one case only are such figures clearly provided, for the Vidourle basin [FLM36]). In this basis, the 4-year action programme plans 27M€ investment and 2M€ administrative costs (salaries for 12 full-time jobs), i.e. a 93%-7% balance. It is planned that a great effort will be made on awareness raising, as well as on assistance in the implementation of some measures (change in agricultural practices, reduction of vulnerability, etc.). Though it is not possible to consider this case as a reference, it shows clearly that this aspect is essential: once designed and decided, flood policies have to be implemented. As most plans put significant efforts on non-structural and information measures, this aspect should be kept in mind: probably that in the past decades, when flood policies consisted much more in building works, human resources didn't represent such a big share of expenses.

Though no comparison of the cost of plans and associated measures is possible (e.g. surface and population of the basins are very different, flood issue raises in several ways, etc.) it is easier to consider this information on a common basis: the yearly cost (see table).

Overview of the cost of the measures of selected action plans

Basin	Overall cost of the measures (M€)	Duration of the plan		Annual cost (M€/yr)
		Period	Duration	
Rhine	1 900	1998-2000	2 yrs	950
	4 520	1998-2005	7 yrs	645,7
	12 300	1998-2020	22 yrs	545,5
Loire	~100 - ~600	none	none	-
Vidourle	29	2003-2007	4 yrs	7,25
Moselle	54,5	1998-2000	2 yrs	27,25
	224	1998-2005	7 yrs	32
	500	1998-2020	22 yrs	22,7
Oise-Aisne	172	2000-2006	6 yrs	28,7
Saône	37	2002-2007	5 yrs	7,4

(1) Proposal of action plan not endorsed by public authorities. No duration is proposed.

Besides, as mentioned in Chapter 2, an important point to bear in mind when considering these costs is the “intention dimension”:

- the longer the term of the action plan (e.g. 2020 for the Rhine) the higher the uncertainty regarding the real amount of implementation but also the reality of the expenditures: many events may lead to reconsider expenses, either to reduce them or to accelerate the rhythm of implementation if a severe flood occurs, etc.
- figures provided in the plans are generally approximates in order to present rounded off results. E.g. “exactly” 500 M€ for the 1998-2020 Moselle-Sarre action plan [FLM63b]. E.g. the strategy for the Middle Loire basin is based on rough estimates both because of uncertainty of figures and because this allows to determine orders of magnitude [FLP11]. Such symbolic figures also have a communication goal;
- in times of public funds shortages, it is unsure that such expenditures may be done over the years. To some extent, a possible “competition” may occur between implementation of the measures and the awareness of flood hazard

Therefore, as considering only figures indicated in action plans may be misleading, it is necessary, whenever possible, to compare such announcements with assessments and figures on expenditures in order to determine whether these amounts are only intentions or are actually invested.

Yet, information is not easily available: whereas announced costs are compiled –with more or less precision- in a single document (i.e. the action plan), figures on expenditures are rarely formally compiled. The main reason is that lots of institutions, public authorities and partners take part to the implementation of the plan, then to its funding. E.g. in Germany Länder, Landkreise, cities or municipalities may take measures. E.g. in France, cost are shared among municipalities –both individually and via *syndicats de communes*, several ministries, departments and specific groups of users in some places. As a consequence, information is sparse both among institutions and among several parts of budgets. Gathering of information is then almost impossible.

To this regard, it is interesting to indicate that the action plan for the Rhine and those based on a similar pattern (Moselle-Sarre, Meuse...) formally include a chapter on the evaluation of the implementation. As they were all adopted in 1998, they set the followings interim deadlines: 2000, 2005 and 2020 for the final deadline, each deadline associated to specific operational goals. On this basis, cyclic evaluation process is planned, on a 5-year basis. Some of these assessments have already been published.

Besides, other assessments are made or are possible for other basins: the Loire and the Oise-Aisne.

Thus, several documents provide some compilations of the costs of the measures taken.

From a general point of view, comparisons of these elements are not conclusive:

- interim goals are not always set, then formal assessment is not possible
- besides it is unsure that tables of expenditures are representative at all of the quality of the implementation (apart when level of expenditure is very low, probably...).

Given this, no trend arises regarding the degree of implementation of several plans:

- it seems good in the Moselle-Sarre basin and to a lower extent in the Rhine basin
- it seems rather poor in the Loire
- little information is available for the Oise-Aisne basin and also, to some extent, in the Meuse basin

For most interim assessments available, operational efficiency of the measures and level of achievement of goals are very difficult. What is clear in most cases is that there is clearly a new dynamic launched and that enhanced efforts are being made regarding protection against floods.

i- The Rhine basin

a- Situation in 2000

ICPR issued a detailed document in January 2001, describing the situation in each member state [FLM10]. At Rhine scale, the following statements were made:

- regarding the reduction of damages: the goal has not been achieved. The main reason is that when the goal was set by the plan, local measures that were already being implemented led to opposite effect (urbanisation behind dykes, increase of stakes in floodplains...).
- regarding the flood level, it was considered that the 2000 objective was almost achieved when the evaluation was processed. ICPR estimated that the completion of several on-going works (increase of retention capacity, extension of floodplains..) would ensure achievement of the goal in 2001.
- regarding public awareness, the results were good and ICPR indicated that the 2005 goal for mapping was to be achieved by 2001 as far as the fluvial corridor was concerned. As a supplement to efforts made by member states, ICPR has prepared atlas of flood prone areas and of damages. Lots of efforts have been made, both by ICPR and by member states to communicate and raise public awareness on flood risks: conferences, leaflets, public meetings...
- regarding flood forecasting and announcement, the goal was achieved for all stretches of the Rhine ie. 18 hours for high Rhine, 36 hours for upper, middle and lower Rhine; 72 hours for the delta.

The implementation of the action plan has generated a genuine dynamic within ICPR member states for the definition and the implementation of flood policies. Further efforts remain necessary in particular to make all actors aware of the risks in order to reduce potential damages.

From a technical and financial point of view, the situation in 2000 was as described in the following table.

Implementation of the Rhine action plan on floods – Situation in 2000

Measures		Protection effect vs floods Operational goals (1)				Measures		Estimated expenses (M€)	
Code (2)	Detail	1	2	3	4	Goal	Result	Goal	Real
INFa	Communication	++	+	+++	-	50%	> 40% on tributaries	13	33,8
	Mapping		+++	+	+++	-	100% on the Rhine		
INFb	Increase forecasting period	+++	-	+++	-	50%	50%	4	
	Improve announcement systems	+++	-	+++	-				
PREa	Extensification of agriculture (km ²)	+	+	+	-	800	>950	135	<250
PREb	Reduce impervious areas (km ²)	+	+	+	-	90	>10	70	unknown
PREc	Restore streams (km)	+	+	+	-	1280	>1010	129	125
	Re-revitalise flood plains (km ²)	+	+	+	-	100	>100	250	
	Develop nature, re-afforest (km ²)	+	+	+	-	450	>865	88	>120
	Create works for retention of floods (Mio m ³)	++	+	+	-	4	>2,6	50	>69
	Re-revitalise flood plains in the fluvial corridor(km ²)	++	+++	++	-	5	14,2	60	150
PROb	Create works for retention of floods in the fluvial corridor (millions m ³)	++	+++	++	-	33	10 (2000) +32 (2001)	136	9,7
	Maintenance and strengthening of dykes (km)	++	-	+	-	730	730	662 (corr NL)	868
TOTAL								1900	>1630

(1) Legend: + low impact; ++ medium impact; +++ strong impact; - no impact

(2) These codes refer to specific typology of measures established for the present project. A specific fiche has been established for each measure.

This table shows that there may be significant gaps between estimated costs and real expenses. Given the fact that member states may have launched measures with the highest cost-efficiency first, it is not possible to draw general statements based on these figures. However, it is important to note that financial estimates are very difficult:

- some expenses are much lower than expected. E.g. the technical goal set for the creation of works for retention of floods in the fluvial corridor has been achieved at a cost almost 15 times lower than planned. E.g. the goal for restoration of streams and re-vitalisation of floodplains was almost achieved for one-third of the expected cost.
- some are much more expensive. E.g. expenses for communication and mapping activities were 2,5 more expensive than planned. E.g. extensification of agriculture: although the result achieved is a bit higher than the goal (20% more surfaces), expense is almost 85% higher than expected.

b- Situation in 2003

In 2003, an informal state of the art of the implementation of the plan was issued by ICPR, covering the 2001-2002 period [FLM69].

Continuous efforts have been made by member states. Although this evaluation is not as detailed as that issued in 2000, some facts can be highlighted:

- in Switzerland, expenses for the protection against floods on the Rhine basin have reached 60 M€ in 2001 and 87 M€ in 2002
- in Germany, maintenance of dykes has proven efficient during Moselle and Lahn floods (2002-2003).
- 150 km of dykes have been restored in the Netherlands in 2001-2002. Altogether 825 km have been improved since 1995.
- in France, several legal measures have been taken, either at local level (integration of flood hazard in land-planning documents) or at national level (new set of legislation applying to activities likely to increase impervious areas and specific technical constraints to integrate in such projects)
- mandatory planning measures have been implemented in several sectors of the Rhine basin
- several polders have been built or restored in the middle Rhine in Germany and in France. Storage capacity for Germany alone has reached 71Mm³.
- many initiatives have been taken regarding raising of public awareness on flood risk, both by member states and by ICPR itself. In particular, a handbook has been published; it describes measures for reducing damages and provides lots of elements regarding their effectiveness [FLM12].

c- Situation in 2005

The next evaluation will be issued in 2005. It is not yet available at the time this report is prepared.

The interesting point with this third assessment is that it is based on a common methodology and will then not be a simple compilation of selected national examples. Besides, on some indicators, national aspect will not be considered: information will be provided at stretches scale.

ii- The Loire basin

The proposed strategy has not been adopted as the official strategy for the Loire. Thus, it is not implemented as such. Some proposals are followed, but in broad terms, minimum actions are carried out i.e. the necessary ones (e.g. forecasting, maintenance of dykes) and the cheapest ones. Three groups of actions must be distinguished:

- most efforts take place in “*contrats de plan*”, contracts signed every 6 years between central government and each region in order to determine common projects and associated funding schemes. Actions on the Loire (not only regarding floods) are funded within this frame: they are included in 7 such regional plans, in order to cover the basin completely. Actions launched in this context may be less homogeneous: what is done depends on local factors, not

necessarily on the degree of priority with regards to flood hazard at basin scale. In practice, the level of expenses is lower than planned [FLM15][FLM16].

Financial involvement of the state in the Loire basin at regional scale

Total of expenses planned on floods between 2000-2006	Amount of actions launched during the 2000-2003 period	Payments actually done between 2000 and 2003.
55 M€	21 M€	12,5 M€

The above table provides figures for state expenses; similar statement applies to all local authorities, event in areas with higher flood hazard. E.g. actions regarding flood protection of cities of Orléans and Tours (the most vulnerable areas in case of a major flood [FLD06]) were negligible between 2000 and 2003: they respectively spent 7000 € (for preventive information) and 0 €.

- some actions are also carried out at basin scale in order to implement the “*Plan Loire Grandeur Nature*”, associating central government, Loire-Bretagne Water agency and *Etablissement public Loire* (an association of local authorities from all the basin).

For the 2000-2003 period, central government has spent exactly 50% of what was planned between 2000 and 2006 (2 M€ *vs* 4).

For the other two partners, goals were set in terms of actions. Thus expenses can’t be compared to previsions. In practice they respectively spent 1,3 M€ (100% for metering stations) and 8 M€ (83% for metering stations) between 2000 and 2003.

- initiatives may also be taken apart from these contracts. E.g. central government engaged 2 M€ between 2000 and 2003 for preventive information, flood forecasting, maintenance of dykes...

iii- The Meuse basin

It is difficult to have an overview of what has been done in the Meuse basin. Indeed, financial figures are partial and means for assessment are thus limited. Besides, although the plan was adopted in 1998, figures cover the 1995-2001 period, then include actions independent from the plan itself. Only general statements may be provided here, picked from the interim evaluation of the implementation of the plan [FLM47]:

- for the 1995-2001, 230 M€ have been invested in projects aiming at the reduction of the risk of damages. Some large projects have been carried out apart from the plan also. Then the assessment of the plan only gives a partial view of what was done in the basin;
- at basin scale, ICPMS judges that the risk of damage did not increase in the period, compared to the 1995 situation (considered as the basis for reference). The working group even suggests that the level of risk has decreased thanks to efforts regarding the reduction of vulnerability, the information of the public, forecasting and alert.

iv- The Moselle-Sarre basin

In 2001, the first interim evaluation was issued [FLM80]. It covers the 1998-2000 period. As for the Rhine first evaluation [FLM10], no common methodology was applied by member states. Therefore, the document is an inventory of what has been done in each country rather than a proper assessment. The only indicator used is the amount of money spent compared to previsions. From this point of view, the situation is very encouraging: amounts spent are 70% higher than planned (93 *vs* 54,5 M€).

Given the lack of detailed information, it is only possible to compare expenses made per set of measures (see table below).

	Planned (M€)	Spent (M€)
Reduction of the risk of damages	22	49
Continuation of the improvement of flood forecasting and announcement systems	0,5	1
Increasing the retention of water	32	43
Total	54,5	93

Thus, from the financial point of view, goals are achieved. Yet, there is no data available regarding operational goals. Facts and projects carried out can only be listed. The following are some of the most significant ones:

- the 3 countries have taken several initiatives for the elaboration of atlas of flood prone areas, either on their own or jointly (e.g. Luxembourg and Rhineland-Palatinate, for 1,75 M€). France has prepared a single document for all the French part of the basin; overall cost was 0,9 M€;
- measures have been taken to ensure local protection. Rhineland-Palatinate spent 18 M€ for such measures on Moselle, Sarre and Sûre basins. Saarland invested 7 M€ in order to create a new retention basin of 800 000 m³ capacity. Luxembourg spent 0,3 M€ for a 530 000 m³ new retention basin.
- all 3 countries have improved flood forecasting and announcement systems. Existing tools have been upgraded, new stations have been integrated in existing networks (e.g. 36 in France), hydraulic models have been elaborated for better simulation of flood events then for extended warning periods (e.g. Rhineland-Palatinate has worked on a model at basin scale), all countries have set up websites providing detailed information
- a joint Luxembourgesse-German project was carried out between 1999 and 2001 to improve natural retention capacity of riverain areas: new tree species were planted, large bands of land have been restored along the rivers... This INTERREG project costed 0,6 M€. Similar measures have been implemented in the German part of the basin too (e.g. adapted agricultural and forestry methods in 450 km²).
- Saarland awards more than 10 M€ / year to municipalities implementing specific policies aiming at reducing impervious surfaces and at improving performances of pipes collecting wastewater, all this in order to reduce the run-off in time of heavy rainfalls.
- in all countries several measures have been implemented to ensure large information of the public and awareness raising: leaflets, websites, maps, practical manuals...

On the whole, results of the measures taken by member states are judged as a success. Yet, the level of reduction of the risk of damages is difficult to assess without specific criteria that are still to be developed.

v- The Oise-Aisne basin

Though it lasts for only 6 years (2000-2006), the action plan for the Oise-Aisne basin [FLM37] also includes an interim assessment.

It was published in 2003 [FLM81] but information provided is very limited: no data on costs, and only main facts. Yet, assessment on such a short period may not be much deeper.

In all fields of activity identified by the Charter, measures have been taken. A very synthetic list is provided in the document:

- development of new forecasting systems
- information of the public with online atlas of highest levels of water reached and daily bulletins available on internet
- coherent municipal plans in most municipalities (either established or launched)
- all administrative procedures for maintenance and restoration of the channel (dredging, extraction of sediments...) are ongoing. They are compulsory given the scale of the measures planned (e.g. 750 000 m³ of contaminated sediments to dispose of).
- identification of priority sites for the construction of new storage capacities: 10 projects are either already being prepared or planned in order to carry them out by 2006. They represent 35 Mm³ storage capacity and 1550 ha to be over-flooded. Investment costs are estimated at 24 M€ and annual operation cost at 220 000 €. Though decisions have been made, technical studies and administrative procedures take a rather long time.

As for most interim assessments available, operational efficiency of the measures and level of achievement of goals are very difficult. There is clearly a new dynamic launched and enhanced efforts are being made regarding protection against floods.

4.1.3- Identification of the benefits

While detailed elements (both technical and financial) are generally available to describe measures, very limited information appears regarding benefits expected. Indeed, sets of measures are proposed, described and quantified with regards to the general goals. Yet, direct connection is hardly made, partly because expected benefits remain as general goals at plan scale and are generally not quantified. Indeed, benefits expected from a given measure are generally not individualised: the measure is supposed to contribute to the overall goal. Different situations are met to this regard:

- no benefit is indicated or only in very general terms: reduction of damage, reduction of maximum flood depth, extension of warning period, increase of people's awareness... E.g. in the Vidourle basin two main goals are set: improve prevention and increase protection [FLM36];
- express benefit is set: e.g. the action plan for the Rhine ultimately aims at reducing the risk of damage by 25% by the year 2020; at reducing flood levels downstream of the regulated Upper Rhine by up to 70 cm by 2020; drafting risk maps for 100% of the floodplains & flood prone areas by 2005; increasing warning lead time by 100 % until 2005 [FLM09].
- benefits are set in terms of flood frequency that can be face safely (in theory at least). E.g. the strategy proposed for the Middle Loire, if fully implemented, shall ensure "a good level of safety would be ensured for flood with ~200-year return period"

Some properly speaking "benefits" are also expectable from measures, in particular environmental ones. Indeed, flooding some floodplains, oxbows and wetlands may allow some forms of aquatic life to develop. Yet, no literature on this aspect was found.

In order to illustrate these considerations, the following table provides an overview of the benefits formally targeted by measures, as stated in action plans.

Overview of the benefits formally targeted by measures

Basin	Type of benefits targeted in the action plan	Quantification
Rhine	Reduce extreme flood levels downstream the impounded section	Up to 70 cm by 2020
	Increase flood awareness	Drafting risk maps for 100 % of the floodplains / flood prone areas by 2005
	Improve the flood warning system	Prolong the warning lead time by 100 % until 2005
	Reduction of soil erosion	
	Improvement of riparians' security	
	Restoration of habitats; development of new ones; recharge of groundwater bodies	
	Reduction of the volumes of water in sewage systems	
	Security of people living behind dykes increased	
	Reduction of erosion	
Loire	Reduction of vulnerability of existing stakes	Up to 15% reduction of damages
	Efficient post-crisis management	Up to 15% reduction of damages
	Flood peak shaving	Up to 900 m ³ /s
	Flood level reduction	Between 20 - 50 cm upstream Tours and between 5 - 20 cm downstream
Vidourle	Rainwater shaving	Approx. 16% of rainfall in each sub-basin for 10-year return period rains / Approx. 18% of rainfalls at basin scale in case of 50-year return period rains
	Better knowledge of risk and of stakes	
	Securisation of dykes	
	Reduction of hazard in 2 of the main towns	
Moselle-Sarre	Dynamic slowdown of floods	
	Reduction of damages (with reference to 1998 situation)	By 25% by 2020
	Extension of forecasting period	Up to 12 hours by 2000 and up to 24 hours by 2005
	Optimisation of the functioning of gauging stations and of warning systems	
	Improvement of emergency plans	
	Increasing of riparian populations' security	
	Increasing of awareness of populations	
	Preservation of historic urban sectors	
Restoration of habitats; development of new ones; recharge of groundwater bodies, prevention of erosion		
Oise-Aisne	Reduction of the level of water (compared to 1993 flood)	By up to 20 cm (15 cm in most places) due to priority works By 15 to 45 cm (over 30 cm in most places) by 2012 when all works will be done
Saône	Reduction of vulnerability	

It is certainly not always possible to determine specific benefit expected from a given measure as benefit comes rather from the combination of several measures. Besides, very detailed information may be necessary to quantify benefits (e.g. advanced hydraulic model of the basin) and it is not always available due to high costs of such models for instance (e.g. in small basins).

Yet, this probably indicates that in many cases measures are decided without formal analysis of the associated benefits but based on other criteria such as:

- a common agreement that measures will be useful in case of flood. E.g. it is doubtless that increase surfaces of floodplains will benefit to downstream areas, without carrying in-depth studies
- a rough balance of expected benefits, expressed at least in technical terms. E.g. for the Vidourle, measures planned to reduce peak run-off are expected to reduce the quantity of rainwater running by approximately 16% of rainfall in each sub-basin for 10-year return period rains and by approximately 18% in case of 50-year return period rains [FLM36]. Yet, as long as such figures are not connected to any estimate of the level of reduction of damages or to mapping of the reduction of flooded areas, they don't give any indication as to their supposed benefit.
- a perceived acceptability of the cost of the measures. E.g. in the Moselle-Sarre basin, full implementation of the plan is supposed to cost 500 M€ between 1998 and 2020 i.e. 23 M€ / year. This may be seen as a realistic amount at this basin scale and detailed estimates of benefits may not be necessary to convince decision-makers.

Though this is somehow an oversimplification, it raises interesting questions regarding the decision making-process (see Chapter 5).

4.2- Information measures

In order to prevent losses of life and to limit damage to man-made assets, it is necessary to provide better and earlier information to the public (referred to as a preparedness strategy in the Commission Communication on flood risk management [FLP03]). This includes flood risk mapping and communication, flood forecasting and early warning systems, as well as flood announcement.

Information measures are closely interrelated with other elements of a flood risk management strategy. In this way, flood forecasting can be used effectively to raise awareness for other flood protection and prevention measures, and thus supports the implementation and functioning of such measures [FLM03] Other information measures such as flood risk maps inform the choice among other measures, e.g. between preventive and protective measures, and form the basis for deciding where and how to implement such measures.

- **Flood risk mapping and communication.** As specified in the Commission Communication on flood risk management, flood risk maps should at least identify areas with frequently occurring flood events, areas with less frequently occurring flood events, and areas where flood events occur very rarely, including dyke failures. Flood risk maps are supposed to increase public awareness of the areas at risk of flooding, and thereby to influence individual behaviour. By providing information on areas at risk, they provide input to spatial planning, and support the planing of investments into flood protection and prevention measures.
- **Flood announcement, flood forecasting and early warning systems.** Such systems play a role once a specific flood event can be foreseen or expected. In the event of an approaching flood, providing timely and reliable information to the public is key to ensuring the effectiveness of any flood risk management strategy.
- **Information dissemination on best practices for flood protection and damage minimisation.** Such information measures are implemented well ahead of a particular flooding event. Activities to raise public awareness of best practices include general information material like leaflets and handbooks, but also information campaigns targeted at specific audiences, e.g. construction industry, house owners, or the operators of industrial installations.

- **Preparation and establishment of an emergency plan.** While the actual implementation of the emergency plan falls under emergency measures, drawing up such a plan and preparing its implementation consists mainly of information measures.

4.2.1- Flood risk mapping and communication

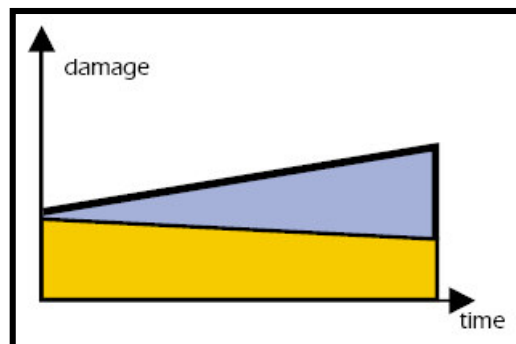
Mapping is considered as a basis in all action plans and at EU scale in order to locate hazard and to take them into account. Hazard maps are both useful for decision-makers and as an information tool for the population [FLM70]. In many cases, maps may even be established independently from flood policies co-ordinated at basin scale, as long as areas are identified as “at risk”.

Zoning ordinances and building codes, that are associated to mapping, are difficult to assess formally in terms of benefits created, for various reasons such as:

- basic usefulness of mapping is information of the public at large (not only individuals). Thus it will only reach this goal if associated to specific communication measures in order to disseminate information as widely as possible. E.g. internet is now widely used to ease and widen access to risk maps
- benefits (if any) are likely to come from a combination of several measures and not necessarily from mapping alone. E.g. mapping alone is mainly useful as an information tool, but full efficiency is brought is combined with land use regulation measures.
- mapping is also likely to create indirect benefit, e.g. it contributes directly to public awareness. In return, public awareness will contribute to adequate behaviour, both *ex-ante* (e.g. adapted building techniques) and during flood (e.g. no use of vehicles).

Without quantification, following trend is proposed: in the long term mapping measures entail a reduction of damage (yellow on the figure), compared to uninfluenced growth (blue). This implies that mapping is taken into account in land use policies.

Illustration of the benefits of risk mapping



Source: [FLM12]

Yet, a CBA of the elaboration of floodplain zoning questioned the distribution of the benefits of such plans, which may be cost-effective for the society but not for the authorities in charge of elaborating them [FLE09]. However, this study applies in a Canadian context and was based on old figures (late 1970s).

Risk mapping is not so much present in action plans considered in detail as part of the project: it appears only in the Rhine and the Moselle-Sarre basins.

ICPR has established atlas and maps at Rhine scale and encourages member states to do the same and to update these documents. A specific effort has been made to develop an atlas of damages, by

combining the identification of areas concerned by risk of floods and (gross) economic estimates of exposed stakes [FLD03]. The fundamental idea from ICPR was to provide a good view of the situation at Rhine scale, though it may be approximate on some aspects. This atlas was intended as an information document; it remains too general to be used as a basis to determine local measures. In line with objective n°3 of the Rhine action plan [FLM09], ICPR expected member states to build on this example to elaborate local atlas that would be much more detailed and accurate, what has been done. In most countries, this is in line with national policies requiring the establishment of risk maps.

It is not planned to update the Rhine Atlas as information at such a large scale remains relevant. However, national or local atlas are updated by member states, as local changes (e.g.: changes in land uses) need to be taken into account for local policy-making.

Interim evaluation of the implementation of the action plan showed that this measure has been fully implemented: in 2000 all the basin was covered by atlas.

In the Moselle-Sarre basin, the 3 countries have taken several initiatives for the elaboration of atlas of flood prone areas, either on their own or jointly. E.g. Luxembourg and Rhineland-Palatinate, for 1,75 M€. France has prepared a single document for all the French part of the basin; overall cost was 0,9 M€ [FLM47].

Regarding benefits expected from mapping, both plans aggregate them among benefits expected from sets of measures: information, public awareness raising, etc.

4.2.2- Flood forecasting and early warning systems

Objectives and benefits of flood forecasting, warning and response systems (FFWRS) have been deeply analysed [FLP26]. It appears that they are considered in different ways throughout Europe, widely depending on experience in flood disasters. Different countries have different expectations for these systems and perceived benefits are thus different.

In Germany, a key objective is to aid commercial waterway navigation; flood warnings to the general public are a secondary benefit. In France and UK (and to a lesser extent in Portugal) the first goal is public safety and property damage reduction, and the alleviation of public anxiety and stress. In the Netherlands, the first goal is resource mobilisation to prevent flooding; general public warnings are considered as a failure of FFWRS.

In some cases, no matter the country, a perceived benefit by flood plain managers and political decision-makers is the avoidance or reduction of politically damaging disquiet and inquiry following a severe flood. This concern also appears in a different form following floods, when social pressure for firm (and often expensive) measures is at the highest. Most plans considered within this research have been designed following severe floods, and they go together with announcement of heavy public expenditures.

i- Flood forecasting

Flood forecasting systems are based on the use of models designed (among other information) with flood records. These documents provide useful information on the functioning of rivers and help determining parameters. E.g. identification of highest floods, level of water of extreme floods, etc.

A key question then is the quality of the information used and its reliability. In general, gauging records provide most elements over variable periods of time. Yet, the shorter the data sequence, the greater the likelihood that it will not be representative, and a flood mitigation strategy based on a short sequence of data may not provide the protection expected. The opposite is true if works are over-designed: they will ensure high level of protection at disproportionate cost.

Quality, representativeness and reliability of information used is thus essential, and efforts to this regard may bring significant benefit. The annual return cost of collection of data may be up to 80 times the operating costs [FLM46]. The benefits from data collection can be anything from twice to one hundred times the cost of collection [FLM67].

The use of historical flood information (old newspapers, articles, reports, historical records, climatic records...) may also be useful to supplement data provided by gauging stations. This approach may place recent events in perspective and may bring a different view than gauging records only. In the example described in the English Midlands [FLM43] a comprehensive record of flooding has been obtained on most basins over a period of 150 years and scattered flood records for a further 100 years or more (gauging records date back 25 to 40 years approx.). The goal is to incorporate this information in flood estimation. Comparison of sources leads to reconsidering frequency of recent floods: one estimate around a 100-year return period based on gauging records, was re-ranked around 44-year RP with historical perspective; another one ranked millennial with gauging records was re-ranked around 175-year RP with historical information. The interest of such a method is that it brings a new perspective and not costly: estimated to several days of historical research. This is certainly a good cost-benefit ratio, despite methodological bias. E.g. areas, land uses, activities, etc. have often significantly changed over decades or centuries, what reduces possibilities for comparison.

From an historical point of view, it can be mentioned that in France, since 1995 law, municipal land use documents established to map risk and to determine specific adequate rules (“*Plans de prévention des risques*” – PPR) are normally based on centennial flood or on the highest flood documented when data is available. This may lead to consider very severe events, thus extending theoretic flood prone areas to a very large extent. Locally, this may be a serious difficulty, and even more as in the past, municipalities used to consider centennial flood only. Take account of the highest flood may lead to significantly change the reference point then may have serious impact on urbanisation constraints.

All plans considered include measures aimed at improving forecasting capacities. From a practical point of view, this includes:

- the upgrading and/or development of modelling tools and their combination with weather forecasts;
- equipment such as extension of gauging stations and flowmeters networks, upgrading of existing systems (e.g. automatisations), radars...

Goal set to forecasting systems is always the extension of forecasting period, e.g. in the Rhine basin 18 hours for high Rhine, 36 hours for upper, middle and lower Rhine; 72 hours for the delta. Efforts made shall ensure that the goal will be fully achieved by 2005 [FLM10].

In the case of the Vidourle, as a flash flood area, flood forecasting and early warning are difficult tasks: in 2002, it only took 7 to 15 hours for water to reach flood alert levels since the beginning of the rainfalls. The most innovative proposal of the action plan with regards to this issue is to set a server online available to mayors that would help them determine the need to implement local emergency plans even before official alerts are launched. Local plans would define levels of actions to be taken depending on the intensity of the flood event. Specific training would be ensured to get the most of this system [FLM36].

ii- Alert

Delay of the alert is essential to allow people organising and taking immediate measures: with 1m of water, it is estimated that a 4 hours delay allows a 40 to 50% reduction of damages in housing (20-30% in shops) [cited in FLD14]. Therefore, a key aspect in organising crisis and post-crisis periods is to ensure quick reaction and implementation of adequate measures.

Efficient alert is the combination of 2 key factors [FLP26]:

- time: delay for reaction once forecasts identify the risk of flood, delay for alert before the flood comes, good timing between alert and flood velocity...
- quality of information: information made available from forecasting (understanding of the hydraulic event) and information disseminated to the public (clear messages and instructions) [FLP08]

Of course human factor is also important: how will people react once alerted (even in case of fully adequate alert)? to what extent will stress impact on their behaviour?... Answer to this questions certainly widely lies in preparedness.

Experience shows that things are complex regarding alert:

- on the one hand numerous constraints have to be taken into account in order to ensure that alert may be efficient: it has to be launched early enough, it shall be clear and precise and shall provide practical information to the population, yet not panic them;
- on the other hand, people don't give any "second chance": if the first alert is not relevant, in-time and useful, later ones are taken suspiciously if not ignored.

Examples show clearly the difficulty to provide efficient alert messages.

In the case of the 1993 Meuse flood, first alert was launched too early by Dutch authorities, then withdrew, then launched again a few days later (on purpose that time). This specific context certainly led to a certain doubtfulness regarding second alert messages, then to inadequate behaviour or too limited self-protection [FLD14].

The same type of statement is made in the Vidourle basin (F): people don't appreciate such hesitations and don't want to bother after 1 or 2 "fake" alerts [FLM36]. E.g. majority of casualties in South-Eastern of France floods were in their vehicles [FLM38]. Yet, staying in a vehicle may turn out to be mortal, as buoyancy is underestimated and a car may already be carried away at a flood depth of 50 cm [FLM12].

The example of 1993 and 1995 floods of the Meuse in its French part demonstrate that despite good information and awareness, quality and relevance of alert also plays a significant role. In these cases, damages were twice bigger in 1995 compared to 1993 figures [FLD14], what is surprising, in comparison with the Dutch example for instance. However, it has to be mentioned that events were quite different in the French case, as level of flood was much higher in 1995. Then, although people took measures to protect themselves (make obstruction to water in front of houses...), they tailored them based on their 1993 experience. Therefore, such protection revealed insufficient in 1995. Several other factors may explain the increase of damages, apart from the characters of the flood itself:

- second flood occurred on a week-end, what slowed the dissemination of information: alert was not launched in time, and as hydraulic phenomena was complex, information provided was certainly not clear enough. Adequate crisis management plan shall take this kind of element into account: although this certainly explains a part of the damage, it is not acceptable (years of efforts and millions € spent for protection works cannot be made inefficient just because flood comes overnight during the week end...)
- besides, large numbers of people were evacuated very early; they could not take any measure to protect their goods anymore then. This shows again the difficulty to launch alert and evacuation procedures at the right time, not too early nor too late...

When alert is relevant in quality and timing, benefits in terms of reduction of damage are clear.

Table below provides information on several slow floods in France: despite very similar situations (70% of houses with similar levels of luxury) human response are very variable.

Number of alerted people depends on several factors: reliability of information, dissemination method, existing level of awareness, etc. In the cases considered, flood hazard has been taken into account only in cases B and C in houses conception. During crisis, the higher the quality of alert, the more relevant behaviour of people (see case E), although preparedness of houses was low. On such statement see also [FLM13][FLD27].

Site	A	B	C	D	E
Flood					
River	Charente	Marne	Marne	Clain	Vienne
Event	1982 / very slow	1983	1983	1982 / rather fast	1982
Frequency T (year)	100	10	25	120-160	20
Depth (m)	0,8	0,4	1	1,6	0,9
Duration (days)	14	17	20	3	3
Alert					
Quality of alert (% population alerted)	Good: 93%	Medium: 85%	Medium: 85%	Ineffective: 32%	Excellent: 100%
Delay of alert (hours)	20	48	48	12	12
Values					
Exposed values for 100m ² houses (k€ 2000)	63	65	65	64	45
Value of goods/value of house (%)	25	25	25	38	50
Population					
Elderly people (%)	46	38	38	49	21
Measures taken before flood (% / house)					
Waterproofness of houses	10	55	43	4	13
Special works	8	13	10	5	7
Measures taken during flood (% / house)					
Obstruction to water	15	17	4	8	71
Removal of cars	81	79	93	66	100
Light goods saved	95	79	81	69	100
Heavy goods saved	57	59	50	33	93

Source: cited in [FLD14]

Similar to alert, time for reaction (T) in case of flood is essential with the view of reducing damages (see table below).

Effect of intervention time-limit (T) after water receding upon damaging percentage

	Water depth <0,80m		Gain (%)	Water depth >0,80m		Gain (%)
	T > 48h	T < 48h		T > 48h	T < 48h	
Agri-food industry						
Capital goods and construction industries						
losses on equipment (%)	90	30	-60	100	50	-50
losses on stocks (%)	100	100	0	100	100	0
Wholesale and retail trade						
Goods and services, Hotels...						
losses on equipment (%)	50	40	-10	100	80	-20
losses on stocks (%)	100	100	0	100	100	0

Source: cited in [FLD14]. Experts' judgements

Action plans considered generally combine efforts to improve forecasting capacities with development and improvement of alert systems, under several forms:

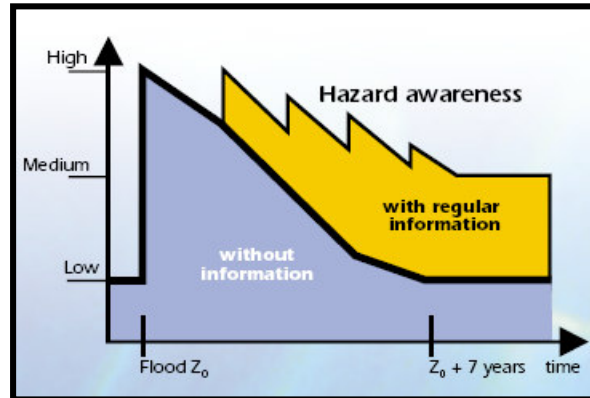
- early warning procedures and optimisation of information flows
- training of authorities in charge of the dissemination of alert messages
- implementation of early warning automatic systems for the information of citizens

Discussions with people following September 2002 flood showed that alert is only taken seriously once: if alert is launched and that no serious (or supposedly so) event comes, many people consider that alert messages are not reliable. Then, they will not behave properly the next time an alert is launched.

4.2.3- Public awareness on best practices

Awareness is fundamental but it doesn't last for long: experts estimate that awareness is back at the minimum 7 years after a flood event (see figure). Continuous measures are thus necessary to keep it higher.

Hazard awareness in time

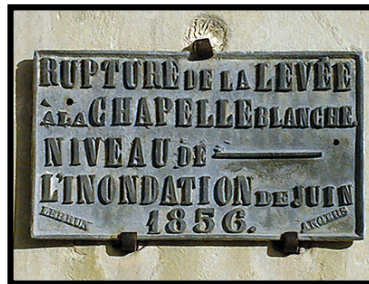


Source: [FLD12]

Flood marks are a simple tool to keep people informed and they are very cheap: 1800 € each [FLM48]; 70 000 € at Oise-Aisne basin scale [FLM37].

Since 2003, it is a legal duty for French municipalities to establish inventories of existing flood marks in flood prone areas and to restore and maintain them. Maps and pictures of flood marks are available on the web for several sectors already (see pictures below).

Flood mark in the Loire basin (F)



Source: DIREN Centre

Flood scale in the Loire basin (F), before and after restoration



Source: DIREN Centre

Such actions are essential to create perception of risk.

In France, a recent survey showed that geographic sectors where the perception of flood risk is the weakest are Paris and surrounding area and the West of the country. Yet, these two regions are considered as potentially exposed to two of the three biggest natural disasters susceptible to occur in France: respectively flood of the Seine and of the Loire similar to those of 1910 and 1856 [FLP27]. Since no severe flood occurred since then in these two sectors, flood risk has been forgotten. In Paris, people consider they are not exposed to any natural risk; in the West, storm is ranked number one, certainly because storm caused disaster in December 2000, only 4 years ago. Flood ranked number one in the surroundings of the Mediterranean sea only, where such events occur frequently: 1988 (11 casualties); August 1991; November 1999 (35 casualties); September 2002 (23 casualties); December 2003.

Measures for raising public awareness on flood are included in all action plans considered in the project (information, training, public meetings, etc.) and this aspect is under several forms one of the pillars of most plans.

The fundamental importance of such measures is widely agreed, while detailed quantification of the benefits is very difficult. Comparison of the level of damages in the district of Cologne in 1993 and 1995 floods of the Rhine provides some evidence of the benefits of awareness in terms of reduction of damages.

Households	Average damage per household		Damage reduction per household
	1993	1995	
All	20 500 €	6 100 €	14 400 €
No experience with flooding	27 600 €	8 100 €	20 000 €
Recent experience with flooding	2 500 €	1 900 €	600 €

Source: [FLM12]

1993 and 1995 floods of the Meuse on the Netherlands provide the same evidence (see next page).

Overview of the differences between the floods of 1993 and 1995

Category		1993	1995	Dif. 93 - 95
Hydrology	peak water level at Borgharen (m + NAP)	45.9	45.7	+
	peak water level at Sambeek Boven	13.92	14.02	-
	peak discharge (m ³ /s)	3120	2861	+
	duration* ¹ (h)	127 (5 d)	175 (7 d)	-
Forecasts	time in advance of a good forecast at Borgharen	14	12	+
	forecasts quality	mostly underestimate	mostly overestimated	
Flooded Areas	total flooded area (ha)	17000	15500	+
	area of private persons (ha)	345	209	+
	area agriculture/woods (ha)	8614	7318	+
	area industry (ha)	157	99	+
Damage to private persons	num. of damaged houses* ²	5580	4424	+
	damage furniture (kfl)	36283	6782	+++
	damage houses (kfl)	44479	33208	+
	damage cars (kfl), gardens, camp sites, recreation houses	15750		
	damage camp sites/recreation houses		7965	
	number of agricultural damage reports	473	664	-
Damage to agriculture and horticulture	agricultural damage* ³	19375	20869	-
	damage to glass houses	8842	5091	+
	damage to other categories of agriculture than glass houses	10534	15777	-
Damage to companies	damage to industry (kfl)	12070* ⁴	10226	+
	damage to construction companies (kfl)	2612* ⁴	-	
	damage to trade and recreation businesses and the hotel and catering companies	47171* ⁴	42266	+
	damage to the provision of services	9046* ⁴	5978	+
	unknown category of company		3730	
	total companies	70900	62200	+
Damage to institutes	damage to institutes and organizations	2581	2126	+
Damage to the government	damage to governments buildings and sites	6545	529	+
	damage to river infrastructure	21932	1500	* ⁵
	damage to land infrastructure	15432	18047	-
	damage to public utilities	7302	unknown	
	other governmental damage (cleaning, assistance)	10038	19100	-

*¹ Duration = hours that the water level of 45 m is exceeded at Borgharen.

*² Number of damage houses is assumed to be the number of damage reports that are received.

*³ Agricultural damage includes damage to the agricultural buildings, machines, crops, animals, and costs to vacuate animals, machines etc, costs to build emergency dikes, etc.

*⁴ Damage to the cities in the province Brabant (Boxmeer, Cuijk and Vierlingsbeek) is included in the damage of 1993 (respectively 140, 0, 405, 26.2 kfl for the four categories). In 1995 these cities are not included.

*⁵ This comparison cannot be made, because in the damage of 1993 also costs are included which originated from maintenance that also would have been done if there were no flood in 1993 and improvements of the river works.

Source: [FLM13]

Both events were globally similar from physical and hydraulic points of view. However, while awareness may have been low when 1993 flood came, this was not the case in 1995 anymore. At the same time, measures had been taken in between, esp. with regards to public information. The result of both changes appears clearly regarding damages to furniture, a category for which good information and awareness allow significant benefits in terms of reduction of vulnerability. In 1995 the amount of

damages in this category was reduced by 81% compared to 1993. As delay was short between the two floods (11 months) significant changes were not possible on infrastructure, structure of buildings, etc. Yet, damages to most activities were reduced in 1995 compared to 1993 (see table)²⁷.

General table of damage according to land use and activities in the Netherlands Meuse flood

	Houses	Industry - Businesses	Public buildings	Roads	Agriculture	Total
1993 flood (M€)	43.4	33.3	14.1	7	8.7	106.5
1995 flood (M€)	18.3	28	1.8	8.1	9.4	65.5
Gain (%)	-58	-16	-87	+16	+8	-38

Source: [FLD14]

In the case of agriculture, though overall amount increased, the cost/claim ratio decreased by 25%. Although very empirical, these figures demonstrate benefit of qualitative, reliable and in-time information.

The majority of action plans considered include measures aiming at increased public awareness.

Several types of information to the public are planned: leaflets, websites, public meetings, flood marks, guidance books, etc. Two cases deserve specific attention as they go further than these general measures:

- in the Loire basin, as there has been no serious flood on the middle Loire since 1907, it is not clear whether decision-makers will be able to understand and analyse properly data that would be provided in time of flood [FLP11]. In such times, figures and data may appear unbelievable compared to common knowledge about the river and usual figures. Yet, they have to be taken seriously in order to cope with crisis properly. Such a situation was observed in the Oder flood in Poland in 1997 and was a factor aggravating the damages. Preparedness is essential, not only in terms of behaviour but also regarding the acceptance of the idea that flood may occur and may be severe. This applies to all actors involved: decision-makers, citizens, etc.
- in the Vidourle basin, it is proposed to create an Observatory that would play as a local resource centre on flood risk: collection of detailed data on past events, dissemination of information to decision-makers and to the population, follow-up of the implementation of the action plan, etc. [FLM36]

Surveys following the September 2002 flood showed that even when people know that flood may occur, they often don't believe that it creates serious hazard and they are not aware of how violent the flood might be. This leads to risky behaviours and slow reactions when flood comes.

It is planned to carry out a biennial survey to determine to level of awareness and of preparedness of the population. This will help designing communications measures in the most efficient way.

Great effort is planned for this measure: 5 full-time people are necessary to properly implement it.

Once again, the question of the benefits generated by these measures is hardly addressed: either no element is provided, as in most cases, or the measure is supposed to generate benefit as part of a wider set of measures. E.g. in the Loire basin, awareness raising will contribute to the reduction of damage together with measures reducing vulnerability and reducing the use of floodplains.

²⁷ It has to be kept in mind however that most exposed goods had probably been destroyed in 1993 and certainly not (yet) renewed or rebuilt by 1995. This leads to a "mechanic" reduction of the level of damages between the two events.

4.2.4- Establishment of an emergency plan

The importance to establish an emergency plan is clear: in time of flood, all actors likely to take part to relief and rescue have to be as efficient as possible: they have to be available, and so do equipment required (adequate vehicles, pumps, boats, sand bags...), co-ordination has to be immediately efficient, etc. Though all this seems obvious, in some recent cases in France, rescue centres as well as fire stations were among the first buildings flooded and were then out of order.

As emergency plan is not managed and elaborated by authorities in charge of water management, this aspect is hardly included in action plans. Yet, experience shows that in time of crisis and post-crisis, it is not only a matter of rescuing people: specific measures are needed to reduce damages (see point 4.4 below). Therefore, design of emergency plans shall not be set aside from the elaboration of flood action plans: connections with relevant authorities (civil protection and security services) would certainly be relevant.

Drawing up an emergency plan and preparing its implementation consists mainly of information measures. It is a matter of organisation and of planification that is acknowledged as fundamental. Yet, only two plans formally integrate such measures: the Loire and the Vidourle ones.

In the Loire, it is considered that culture of the risk is not enough: crisis situation shall be organised and properly managed [FLP11]. This measure includes *ex-ante* actions: preparation of local emergency plans in all municipalities, organisation of all people who would participate to their implementation (at Loire scale, this means that this shall be organised no matter administrative borders between regions, departments...), etc. Training exercises would be highly useful (and would also improve the awareness of the flood hazard).

All these actions would be combined with post-crisis measures (see below).

In the Vidourle, the situation is a bit specific: as flash flood are very sudden and last for a very short time, it is necessary to organise precisely emergency plans. In 2002, the flood reached the highest level in 7 to 15 hours after beginning of the rain and 2 days later, all rivers were back within the limits of their minor beds. In such circumstances, lead-time is fundamental, probably even more than in fluvial floods.

Specific plans include the identification of “who does what?” but also all practical information such as where people and livestock shall take refuge in time of flood, what materials means shall be made available (and where? when?), how would people be evacuated and where to, etc.

It is proposed to set a common scheme at basin scale so that elaboration of plans would co-ordinated and plans would be homogeneous. The same statements apply to road plans and similar actions would be taken.

As far as benefits are concerned, this concept appears somehow theoretical: the question of not having any plan is irrelevant. Then, benefits appraisal would require to identify the share of damages that has been avoided (or not) thanks to the plan. No information on this aspect has been found in literature.

4.3- Prevention measures

Whereas a protection strategy puts an emphasis on constructive measures, flood prevention typically aims to minimise flood risk through their management. Based on the idea of “giving rivers more space” and enhancing the natural water retention capability, this policy aims to limit effects of flooding either by minimising damage potential, or by preventing the occurrence of floods altogether. The main types of preventive measures are the following:

- **Limiting the use of flood plains:** certain uses of floodplains can be eliminated altogether through land use planning, e.g. by ruling out new construction in high-risk areas. Alternatively, insurance can be used to provide economic disincentives, e.g. through higher premia for high-risk areas. Agricultural policies can support extensive agricultural uses of floodplains, which are less vulnerable to damage.

- **Enhancing the retention capability of soil:** Appropriate soil uses and vegetation cover in upstream areas can enhance the absorption and retention of rainfall, thus limiting run-off. This can be supported through agricultural policies, influencing the crops grown and thus the vegetation cover, but also through measures to reduce soil compaction and sealing.
- **Enhancing the retention capacity of floodplains and riparian wetlands** through renaturation of morphologically changed water bodies, reconnection of riparian wetlands and oxbow lakes, support of meadow woodlands etc.²⁸

It is clear that a prevention strategy will need to be particularly well integrated with policy areas like spatial planning, land use and agriculture. The interests of different users (e.g. shipping, industry, water supply, housing, etc.) have to be considered and integrated into the planning process, along with the objectives of nature conservation and sustainable river management.

4.3.1- Limit the use of floodplains

Two main types of measures are planned regarding the limitation of the use of floodplains:

- extensification / adaptation of agriculture
- tight control of land use, esp. limitation of urbanisation

Such measures are closely connected. Indeed, as all flood prone areas constitute flood plains, it is important to:

- preserve as much as possible their capability of controlling the floods by maintaining the specificity of certain areas that are liable to flooding but are not built-up (agricultural areas or very few houses) and where the floods can spread and dissipate their energy with few damage. The new embankments, dykes and constructions must be strictly forbidden regardless of the characteristics of the risk (height and velocity of the water) ;

The management of floodplains by farmers shall be considered as much a business as agricultural production itself. EU policy shows this evolution in encouraging farmers to manage their lands to prevent flooding: creation of rows of trees and anti-erosive banks, ploughed lands converted into meadows... Still, such measures are not yet well received and remain in most cases experimental rather than deliberate will of integrating this new agricultural functionality.

- restrict the opportunities of building and of carrying out works of protection to the sole areas where the current urbanisation is important. These areas must be strictly delimited. It will be necessary to lower the vulnerability of the existing constructions in these areas and to strengthen the protection of the constructions that could be authorised, according to the risk. Steps will be taken more specifically to ban building in urban areas where the risk may endanger people's lives. Specific regulatory plans, documents or measures exist in most countries in order to delimit the areas that are exposed to the risk, taking into account the nature and intensity of the incurred risk, and where the activities and buildings are banned or subject to conditions. It is also possible to identify in such plans areas that are not directly exposed to risks and where constructions, works, farms, craft or business concerns and developments are subject to restrictive measures when they are likely of aggravating the risks or of creating new ones.

In most cases, such actions shall be carried out at very local level:

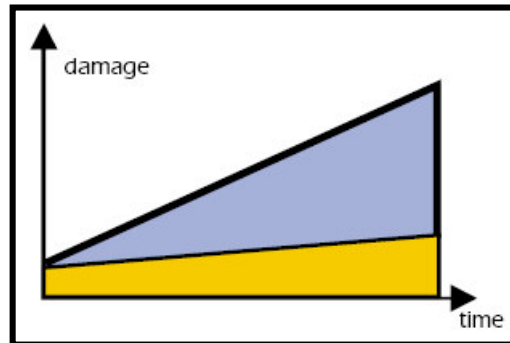
- municipality in most cases for land use regulation, in particular limitation of urbanisation through building permits
- individual farmers for adaptation of production patterns

²⁸ Such measures will also serve to reduce flow velocity. In this sense, they can be linked to habitat engineering measures as discussed above under the heading of flood protection.

However, in order to ensure that these policies are developed are large scale, voluntary and active actions shall be taken at basin level so that these measures don't depend on individual initiatives only. To this regard, the Vidourle action plan intends to develop large-scale actions with farmers, based on concertation [FLM36].

It is demonstrated that when flood prone areas are kept opened, the increase of damage is marginal over the time (yellow area on figure below) contrarily to what happens in developed areas (in blue on the figure).

Evolution of the risk of damages in flood prone areas



Source: [FLM12]

Land use control is a key to ensure that open areas are kept; however, this is much more difficult in dense areas. The basic set of measures proposed in the Loire strategy includes actions to this regard, particularly where all municipal territory is included in flood prone areas (50 municipalities) [FLP11]. Such situation is also common in the Vidourle basin, where the majority of municipal territory is exposed to flood with return period of less than 10 years [FLM36].

Develop floodplains is often quite difficult in practice. Indeed such actions require in many cases that public authorities buy riparian properties. Procedures for doing so are generally long and complex, and in many cases such parcels are often expensive depending on existing activities. This may seriously hinder the implementation of flood prevention policies [FLM30].

Besides, evolution of agricultural patterns also takes time as it is necessary to inform farmers, to consider possible alternative activities, relocation of existing production in flood prone areas, etc.

As for other measures regarding floods, it is important to address such policies at basin scale: indeed upstream areas cannot be expected to bear all constraints in order to ensure protection downstream. Some form of compensation could be implemented given the development constraints that may be imposed.

Action plans for the Rhine and for the Loire include specific effort with regard to the limitation of floodplains:

- in the Rhine, extensification of agriculture is recommended in 3900 km² over the basin, for an overall cost of approximately 1700 M€. No specific direct benefit is associated to this measure, that would contribute to the overall goal of reduction of damages. Indirect benefit could be the restoration of habitats and the development of new ones, as well as the recharge of groundwater bodies.
- in the Loire this measure is a fundamental aspect of the “basic set of measures” considered in the comparison of scenarios. It requires awareness from decision-makers and integration of flood hazard in land planning policies: types of use of land, planification in order to pre-empt available land, etc. Concertation at local scale is thus essential among municipalities to organise their development in co-operation. This applies in particular to the 50 municipalities

that are completely located in flood prone areas: though it is not realistic to relocate all population nor to completely stop their development, it is not possible to do as if no risk would exist. It is thus necessary to find a solution in between.

61 to 76 M€ investment are planned for this measure supplemented by 0,75M€/year for operation [FLP11]. It is estimated that the reduction of vulnerability of existing stake that would be generated by this measure could lead to a 10 to 15% reduction of damages.

The implementation of such measures would require a lot of concertation efforts at very local scale, thus the availability of dedicated human resources: a significant effort to communicate with professionals and to involve them in the decision-making process is indeed necessary. E.g. the action plan for the Vidourle basin (850 km²) expects that 2 full-time jobs will be dedicated to co-operation and concertation with farmers in order to involve them in flood policy and to assist them in adapting professional methods to flood hazard [FLM36].

4.3.2- Increasing retention capability of soils

Contrarily to overflow floods, run-off floods occur most often after violent and localised storms. The waters rush down the slopes, use uncontrolled routes and end up in the bottom of frequently built-up valleys, where they may cause important damage. Indeed they may be accompanied by mudslides. The modes of soil occupation often determine the seriousness of the phenomenon.

Increasing retention capacities of soils is made through actions in two sectors:

- the agriculture sector: several methods and works may accelerate run-off. E.g. hedge uprooting, parcel draining, ditch and stream re-calibration that often go with re-allocation of lands to create larger territorial units. Two main groups of techniques can reduce the negative effects of run-off waters:
 - agronomic measures: changes in cultivation practices in order to improve the capability of soils to retain run-off waters. E.g.: a vegetal topping of soils in the winter, ploughed lands converted into meadows, change in land working methods (avoid the compacting generated by too heavy tractors), crop diversification as it may improve the filtering capability of the soil.
 - hydraulic measures: the purpose of these measures is to lower the flow of run-off waters, accompany the water downstream without damage for the soil and the houses and encourage sedimentation by grazing the route of flows. E.g. grazed strips, vegetal dams, meadows.

To be significantly efficient, these measures must apply simultaneously to a group of parcels and coherently to all the river basin. This implies co-ordination and assistance to farmers as individual initiative is unlikely to be enough

- the urban sector: urbanisation and waterproof soils, which are closely linked, are constantly referred to as responsible and aggravating factors of flooding. Indeed, waterproof soils, which result from intense urbanisation, tend both to shorten the response time because of the creation of artificial flow routes and to improve the volumes discharged downstream what leads to relocation of risk. Moreover, when stormwater sewer system are inadequate and that large works are built (bridges, large roads...), these sectors may sometimes turn into true storage basins what artificially increases damage and the duration of flood.

Land use regulations are fundamental in order to limit waterproofing of soils. So-called “alternative solutions” to rainwater discharge have been developed, that aim at storing the water on the parcel to slow down the concentration time and to erode the flows. E.g. storage structure can be integrated into roadways for temporary storage of rainwater before infiltration in the soil or flow towards an outlet, injection wells, ditches or marshy meadows, draining trenches, filter tanks, etc. When integrated to projects from the beginning, alternative techniques avoid extra costs as they reduce the level of damages in case of flood.

Action plans we considered hardly address this measure:

- in the Rhine basin, it is intended to reduce impervious areas by 2500km² by 2020. Significant financial effort shall be made: implementation of this measure would cost 1900 M€
- in the Moselle-Sarre basin it is planned to increase retention capability of soils in 160km². Cost of the measure is not identified
- in the Oise-Aisne basin also such measure is integrated but it is not quantified: the plan only recommends to implement it.

Benefits associated to this measure are not specifically identified and quantified. In the Rhine it is expected that this measure, together with the increase of retention capability of floodplains and wetlands would lead to a reduction of flood level by up to 10 cm.

Besides, it would reduce the volume of water discharged in sewerage systems, what may be beneficial both for the systems themselves and for the environment.

Yet, despite the clear efficiency of this measure, its concrete implementation is difficult at large scale, as it requires (significant) adaptations to existing constructions, in particular in most urbanised sectors. Besides, it has to be implemented at local scale and to be integrated in local planning documents. In practice, there may be a gap then between action plans goals and implementation. E.g. in the Rhine basin, though the goal set by the action plan for the year 2000 was 90 km², only 10 km² have been covered [FLM10].

4.3.3- Increasing retention capability of floodplains and wetlands

The sustainable management of wetlands must be a key element of the integrated water management. Among the functions and specific values of wetlands, two are of specific interest in terms of flood policies:

- slow down the infiltration and store the water. When this function can no longer be fulfilled (e.g. as a result of a drainage of the wetland), the water flows more rapidly to the rivers and streams, increasing thus the flood risk,
- play as important buffer areas where the water from the aquifer can be stored before being discharged again to the aquifer

Though growing attention is paid to wetlands and awareness develops regarding their role, current trend at large scale is rather leading to their destruction and disappearance [FLE21]. Several factors can be mentioned:

- agriculture, with the drainage of wetlands, the building of dykes, the capture of water for irrigation, meadows converted into ploughed lands...
- the urban and industrial development, with the drainage of lands for new developments, the capture of ground and surface water, the building of dams and dykes, gravel extraction...
- transport, energy (hydroelectric dams...), tourism...

Various types of measures can be implemented for the preservation of wetlands:

- planning measures: water management plans shall define the necessary guidelines for a balanced management of the water resource, and integrate the protection and development of wetlands that are true transitional spaces between the land and the water.
- protection measures, with several legal instruments dealing with the protection of the natural space to ensure the preservation of wetlands: nature reserves, orders for the protection of the biotope, voluntary nature reserves, special areas of protection, designation as Natura 2000 sites, national biological reserves, hunting and fishing reserves, etc.

- land control: local authorities or specific conservatory institutions may ensure protection of these sites through uses control or ecological management for instance.
- financial incentives: e.g. the European structural fund is a basic tool to take more efficiently into account the preservation of these areas.
- agri-environmental measures, based on voluntary services, may give the opportunity of adapting the management of agricultural lands to the environmental stakes of these spaces.

Measures favouring the increase of the retention capability of floodplains and wetlands are included in some action plans. In several cases, they combine this with restoration of streams:

- in the Rhine basin, it is planned to revitalise 1160km² of floodplains by 2020, to restore 11000 km of streams and to develop nature and re-afforest in 3500 further km². This shall cost 5 300M€.
- in the Saône-Doubs basin, though specific actions are planned (e.g. creation of a 1000 ha retention area), main contribution is expected from a specific environmental action programme that is also implemented in the area, with several measures for the restoration and maintenance on many stretches of the river Saône. 10M€ shall be invested in this programme.
- in the Moselle-Sarre basin, 1643 km of streams shall be restored, 70km² of floodplains be revitalise, increase retention capacity would be developed in 270 km² of agricultural areas and in 77 km² of forest areas. The detailed amount of this measure is not available as it is included in a set of measures, next to reduction of vulnerability and increasing retention capability of soils.
- in the Vidourle basin, 5 floodplain areas will be reactivated. They represent a storage capacity of 16 Mm³. Yet, given the cost (2 M€) and the necessary time to implement such measures, only 2 of these areas would be restored during the plan's period (by 2007). The all measure shall be implemented by 2020.

An interesting specificity in this basin is that a significant effort is planned to associate farmers to the protection actions (riverbed and floodplains restoration). 1 full-time job shall be dedicated to this concertation project.

Three main benefits are expected from these measures:

- the reduction of the flood level. E.g. up to 25 cm in the Rhine fluvial corridor.
- the restoration of habitats
- the recharge of groundwater bodies

4.4- Protection measures

This approach has been predominant in the last decades: by applying structural construction measures such as dams and dykes, it allowed floodplains and their hinterland to be put to residential, commercial or industrial uses. Ironically, this may actually have increased the scale of potential damage, as many people living in floodplains overestimate the level of protection so provided. Structural flood protection measures like dams and dykes are designed for floods of a given magnitude and can fail when their capacity is exceeded, leading to potentially catastrophic results. Faced with a changing climate, the limits of this strategy may soon become obvious: even though dykes are built higher and higher and constantly reinforced – at massive economic cost – the risk of breaching dams and rivers reclaiming their original course continues to rise.

Three main categories of structural flood protection measures can be distinguished²⁹:

- **measures which reduce the peak run-off** such as artificial flood control reservoirs or areas for controlled flooding, flood management by dams, or plant and habitat engineering to stabilise river banks.
- **measures which reduce the level of flooding for a given run-off** like channels, dykes, protection and cleaning of riverbeds or river diversion.
- **measures which reduce the possible impact of flooding** on existing structures, such as pile dwelling, reinforcement of buildings, barricades, specific storage of valuable or environmentally harmful goods (e.g. oil tanks, heating, electrical equipment).³⁰

4.4.1- Measures to reduce peak run-off

The main technique for reducing peak run-off consists in building a work of which sole purpose is flood peak shaving. It means that this work must always be empty except during flooding periods. The multiple purpose dams are not advised to reduce floods.

These works permit to store the most dangerous part of the flood and discharge smoothly the water after the critical episode. The location, the volume and operating mode must be carefully chosen. Their impact on environment, on the local human and economic community is complex.

That is the reason why multiple purposes reservoirs are built to increase the value of the reservoir, the location and the investment (water supply, hydroelectric production, tourism...) but they are then generally less efficient to attenuate floods.

Such reservoirs aim at lowering the value of peak discharges downstream. This effect is very clear for mean floods but it may have detrimental consequences on the morphology of the downstream bed: stabilisation of discharge channels in the minor bed, development of vegetation and sediment fixation, all likely to diminish the discharge of the bed in the event of rare floods.

The very big reservoirs may permit really important flood peak shavings at the immediate downstream, about 60 cm to 80cm, rarely more. Smaller structures and diked up valleys usually have smaller capacities which only permit to lower the water stage by 30 to 60cm in the bed.

As soon as we move away from the reservoir itself, the attenuation is less and less important since the river no longer overflows in fields for flood expansion that formerly enabled flood peak shaving. Frequently, fifty kilometres away or after the confluence of one or two tributaries, the attenuation is severely cut down and does not exceed 20 to 30cm.

The dam aims at reducing the flow velocity by storing the water thus keeping part of the sediments it contains. The smallest solids will appear suspended during the next floods, the biggest ones may result in long-lasting small accumulations. This shortage of solids downstream may lead to gradual erosion.

A regular maintenance of the storage areas is thus necessary.

As for dykes, reservoirs often give a false feeling of safety.

Another measure for reducing peak run-off is the construction of transversal embankments in the major bed help to narrow the minor bed and enable to mobilise flood expansion fields.

River works are necessary: a narrowed section permits to increase the floodline, backfill block off the major bed on both sides of the minor bed. The temporarily stored volume of water flows progressively at recession. This type of work is self-operated, nobody has to intervene.

When floods are more important, the narrowed bed that has been created leads to a higher floodline and generates a bigger flood of the major bed. The volume of water is stored thanks to the

²⁹ A similar classification to the approach chosen in European Environmental Agency (2001): Sustainable water use in Europe - Part 3: Extreme hydrological events: floods and droughts, Environmental issue report No 21 was taken

³⁰ Such measures can also be seen as preventive measures according to European Environmental Agency (2001): Sustainable water use in Europe - Part 3: Extreme hydrological events: floods and droughts, Environmental issue report No 21

embankments. It is all the more important when the flooded surface area is wide. The embankments must be equipped with overflow systems in the event of rare or exceptional floods.

The flooding of the lands used as flood expansion fields implies that farmers are granted financial compensations. The interest of such equipment is that river residents have the memory of the floods.

In the area where the bed is narrowed, it is necessary to be on one's guard against the risks of erosion of the bed. Once such precautions have been taken, these structures do not modify the morphology of the bed. However, the slow velocity in flood expansion fields encourages the deposit of sediments which may have either positive (fertile mud) or negative (crops, dirty pastures) effects.

This type of equipment has little impact on the aquatic life in the river and on the biological conditions in the river while it contributes to the reduction of peak run-off.

Action plans considered show that no major work is planned. The case of the Loire basin is very interesting to this regard. Indeed, weirs and levees are very traditional in all the Loire basin and date back to Middle Age [FLM27][FLM28].

For many years, one key question is whether or not building a new reservoir, *Le Veurdre*. Combined with other measures, it would significantly contribute to reducing effects of floods as showed in the scenario). One key finding is that this work alone would not be a solution: though it would reduce level of flood in several circumstances, it would have no impact on the main issue, the vulnerability of dykes and levees.

This option is very politically sensitive: there is indeed a long history of opposition to large works in the Loire basins, with lots of NGOs and citizens struggling to protect the so-called "last wild and natural large river in Europe". Besides, this project may be rather expensive: 10 years ago, estimates were between 75 and 150 M€, depending widely on the implementation of accompanying measures. Although the preparation of the construction of this reservoir was one of the goals of the *Equipe Pluridisciplinaire* when it was set up 10 years ago, decision on this issue has been postponed several times since then and official deadline is now 2006.

In fact, one can see in action plans that "small" works are clearly favoured for reducing peak run-off:

- in the Oise-Aisne basin, it is planned to restore ancient dams and to improve their management for optimised control of surface curve in case of flood on the one hand, and to create several small and medium new reservoirs in strategic locations in the basin. The idea is to implement the dynamic slowdown concept, combine the use of works such as reservoirs with natural floodplains. 24 priority works shall be built by the end of the plan period (2006) representing an overall storage capacity of 17 Mm³. Estimated cost is 11 M€ for this phase, and 58 M€ for the second phase to be carried out by 2012, to create more 65 Mm³.
- in the Vidourle basin, a similar approach is planned. Several reservoirs already exist and provide an overall capacity of 30 Mm³. They were efficient during September 2002 flood, though they are designed for more frequent (thus less severe) events. There also are 5300 ha of wetlands and floodplains in the basin that stored lots of water and slowed the flood in the lower part of the basin.

A significant extension of retention capacities is planned: up to 52 reservoirs of 200 000 m³ average capacity and 10 of 1,5Mm³ average capacity, for a total extra-capacity of 25 Mm³. This would be very expensive and requires some time (studies, construction). As the plan will last for 4 years (2003-2007), only a limited part of the new capacity can be made available. However, it is planned that studies will be launched in order to ensure that all capacities are built within 15 to 20 years. Local geography make it possible to build a significant number of reservoirs disseminated all over the basin, as tributaries may contribute very significantly to flood risk, due to very local rainfalls. It is intended that 10 sites would be created during the plan period, for an overall capacity of 5 to 6 Mm³.

Significant reduction of flood level is expected from all these measures: up to 50 cm in the Loire basin, and up to 35 in the Oise-Aisne basin. In the Vidourle basin, benefit is quantified in terms of share of rainwater run-off shaved: goal is to reach 18% reduction in the case of 50-years return period rains.

4.4.2- Measures to reduce level of flooding for given run-off

Several actions plans considered rely widely on measures dealing with dykes for reducing the level of flooding for a given run-off (Rhine, Loire, Saône, Oise, Vidourle):

- creation of new dykes and levees
- heightening and reinforcement of existing dykes
- creation of local protection, esp. close to places where highest concentration of stakes is identified: settlements, as well as most vulnerable economic activities.

In all these cases, these measures lead to significant financial efforts: investments for these measures account for 11% (Rhine) to 55% (Loire) of overall costs of plans considered.

As far as costs are concerned, some mean unitary figures are provided by the action plan of the Lippe basin [FLM72]

- dyke /increase of dyke: 56 Euro per m³
- wall (lime sand brick): 207 Euro per m²
- wall (concrete): 234 Euro per m²
- partly mobile flood protection: 770 Euro per m²

Benefits expected from these measures are not very detailed:

- the Rhine action plan, that aims at maintaining and strengthening 1115km of dykes, targets a reduction of the risk of damages from such a measure. Yet, once again, benefits are not expressed in a more detailed way. The goal set in terms of reduction of damages is only expressed at plans scale.
- the Loire action plans, some form of benefits are mentioned, in a negative way. Indeed, it is estimated that poor maintenance of riverbed may lead to increase of river flow by 30 to 70 cm, esp. where the stream is narrow (urban sectors). Thus, efforts made in maintaining the basis of levees, in controlling yearly dykes and riverbed relief and in optimising river maintenance works shall contribute to such effect.

History of the Loire basin and hydraulic studies [FLM26] showed the high vulnerability of dykes in case of severe flood, and their resistance is one of the key uncertainties in such situation: it would widely determine the level of damages. This is not only a matter of maintenance: hydraulic phenomena are such that pressure on dykes is then very high and huge amounts of sediments are moved in the riverbed relief, thus weakening dykes basis. Yet, maintenance is essential in order to make dykes as reliable as possible as they are theoretically most efficient in the case of floods with return period of less than 100 years, i.e. the most frequent ones.

- in the Vidourle basin, two main benefits are expected from this measure: the reduction of hazard in two very exposed small towns in the basin that flooded under up to 4m of water in 2002, and the implementation of dynamic slowdown of floods, by the combination of works, storage in floodplains...

The situation regarding dykes and similar works is ambiguous in literature. Although their potential efficiency is well-known and acknowledged, several aspects are pointed out as intrinsic limits.

- ecological aspect: e.g. in the Netherlands, following years of investments in dykes (“dykes ring”...), people have realised that they do not enjoy natural Rhine and Meuse anymore. The expected compensation of such high walls was high security but 1993 and 1995 floods showed that there was no guarantee. Therefore, continuous heightening of dykes was challenged both for aesthetic and ecological reasons [FLM13]. This aspect has been reported in other basins, where riparians don’t appreciate such works (e.g. Loire).

- economic aspect: dykes maintenance is expensive. A strategy widely based on dykes heightening will be difficult to implement in the long-term because of all these “secondary” costs. In the Loire, where the main cause of increase of the cost of damages is dykes breach, this side-effect is formally pointed out and it is considered that flood policy shall not over-rely on such measures [FLP11]. Therefore, the proposed strategy for the Middle Loire recommends important efforts to maintain existing dykes on the one hand but doesn’t promote any significant development of such works. Though this specific cost cannot be expressly identified among the cost of this measure, the large majority of the costs (between 148 and 324 M€) would be dedicated to maintenance and frequent control of dykes, to reinforcement of bench terraces and to maintenance of basis and top of levees.

The history associated to dykes is specific in this basin where “reference flood” occurred in 1856. In fact, the flood itself was a big one (combined with groundwater flood) but not the biggest one (~170 years return period). What made it so severe and dramatic was that dykes were broken in 150 places (23 km) thus becoming useless. Cities of Tours and Orléans were totally flooded and Middle Loire area (1500 km²) was under 1 to 2 meters of water. This specific context is still remembered and leads to moderate confidence in these works.

In the Netherlands, the traditional approach towards flood risk management is based on dike-rings with equal safety levels all over the country. Depending on the location of a dike breach and the size of the flood wave, the direct flood damage may presently range from about 1 500 to 36 000 M€. This wide variability and uncertainty (1 to 24 ratio) is compared to a ‘Russian Roulette’ [FLM58b]

- cultural aspect: it is unanimously considered that the development of dykes creates a false feeling of safety. This leads to an increase of protected values... that may then lead to the need for more dykes as vulnerability increases. In Orléans and Tours, 2 of the most vulnerable cities of the Loire which were totally flooded in 1856, economic development has been quicker behind dykes than elsewhere [FLP11], as people feel (too) safe there. A biased approach is even pointed out [FLM36]: development behind dykes is sometimes presented as a benefit to be expected from the extension of such dykes. In Paris area, in spite of the building of large reservoirs and several such works, a 1910-like flood would lead to damages 5 times higher as safety feeling (and poor awareness of both population and public authorities) led to large development in flood prone areas [FLP17].
- social aspect: in flood prone areas where people who do not enjoy the proximity of the river, demand for more works and faster construction is high. On the contrary, in most exposed areas (close to the river) people see dykes as reducing the benefit of living next to the river. Flood hazard is thus accepted as a counterpart of daily satisfaction (quality of the environment, sight-seeing, fishing, etc.) [FLE17]. Acceptability of the risk from people most directly exposed may sometimes be under-estimated, at least when these people have stayed long enough to become aware of the risk (direct experience of flood, discussion with neighbours esp. old ones, family has stayed in the area for a long time...). Willingness to pay for the reduction of the risk may thus not be linear: at a certain level, flood is considered as inevitable, as fatality; then willingness doesn’t increase anymore. This point is important as it may have impact on how flood policies are designed and on their goals [FLE17].
- safety aspect: if the flood is higher than the reference used to design works, there will be overflow and sometimes breaches and failures of the works that may lead to damages much higher than if the works would not exist. In the Rhine, though one of the most channelled river, 1993 flood caused reservoirs overflow and dykes flooding; damages amounted for 7600 M€ [FLP17]. Thus non-structural measures challenge continuous development of dykes. E.g. compartimentering offers to concentrate water in one smaller area, leading to the reduction of cost of emergency measures (evacuation...). This lowers overall damages (by up to 10-25%) but increases local ones. Next to economic dimension, feeling of safety of population, casualties, natural aspects... should be considered [FLM13]

4.4.3- Measures reducing impact of flooding

A wide range of measures may be implemented in order to reduce impact of flooding. Such measures will not reduce the scale of the flood or the number of sites where specific actions will be necessary in case of flood. Yet, if properly implemented, they will reduce damages on all types of flooded goods and will ease crisis management.

ICPR brought a significant contribution issuing a dedicated publication that details several types of basic measures that can be taken at building scale in order to reduce damages [FLM12]. This document is based on national projects, and widely integrates lessons learnt from recent floods (e.g. in Germany and the Netherlands in 1993 and 1995, in Switzerland in 1999).

An extensive list of practical examples is provided in this document, in four sectors:

- land use control
- flood proofing constructions, both in residential and non-residential sectors
- flood preparedness, both in residential and non-residential sectors
- emergency planning

This publication also proposes estimates of the respective efficiency of such measures.

Measures may either reduce the damage potential or « only » the increase of the damage potential. Effects are estimated as follows.

In this figure, the yellow squares illustrate the quantified reduction of the measures' damage potential. The blue squares indicate measures influencing the increase of damage potential.

Survey of the effects of measures

	land use control		flood proofing construction					flood preparedness			emergency planning		
	keeping areas open	building codes and zoning ordinances	spatial use	equipment	sealing	shielding	hazardous substances	information, preparation	warning	emergency measures	flood fighting disaster control	emergency spillway	financial preparedness
Reduction of increase of damage potential	●	●	●					●					●
Reduction of damage potential			●	●	●	●	●		●	●	●	●	
0 - 25 %													
25 - 50 %													
50 - 75 %													
75 - 100 %													

Source: [FLM12]

Remark: the indicated effects of preventive construction measures are related to moderate water surface elevation (< 2 m). (Yet, as already mentioned, individual protection measures in time of crisis may not be realistic when water depth is over 80 cm. [FLM13])

It appears clearly that some measures may lead to very significant reduction of the damage potential.

It is also clear that the budgetary means are not for all the measures the limiting factor.

The orientation of uses in flood prone areas, which is a very important measure to reduce the risks of damages, and the improvement of the preventive strategies at the level of the populations and of public institutions, do not require supplementary expenses as long as all the modifications or maintenance works already foreseen for the next years are actually planned in the future to be less

vulnerable to flood hazard. This may be a relevant indicator to determine the genuine will and determination of public authorities and of societies at large.

Frequency and intensity are two factors to be taken into account when considering the importance of measures aiming at reducing damages [FLM12]:

- intensity of the flood (esp. water depth) has direct impact on the costs of the measures
- frequency of the flood influences cost-effectiveness and acceptance.

Importance of measures with respect to frequency and intensity

	land use control		flood proofing construction					flood preparedness			emergency planning		
	keeping areas open	building codes and zoning ordinances	spatial use	equipment	sealing	shielding	hazardous substances	information, preparation	warning	emergency measures	flood fighting disaster control	emergency spillway	financial preparedness
Frequent events	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Blue	Blue	Blue
Very rare events	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Yellow	Yellow	Yellow
Low flood depth	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Blue	Blue	Blue
High flood depth	Blue	Blue	Blue	Blue	Blue	Blue	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow

Source: [FLM12]

The yellow squares illustrate the main fields of application of the types of measures, the blue squares rather indicate subordinate uses.

Different approaches to such measures are adopted by action plans

- in the case of the Rhine, measures are national ones, and have to be implemented at local scale. Therefore, estimates of the costs of the damages widely depend on local factors: type of activities and constructions, economic development, etc. Rhine atlas of damages puts it clearly: estimates on the costs of potential damages to housing, though approximate, range from 222 to 340€/m² [FLD03].

Regarding the general goal set at Rhine level (reduction of potential damage by 25% by year 2020), it appears unlikely that the objectives in terms of reduction of damage risks will be achieved as reference values increase year after year. Indeed, as economic value of exposed goods will considerably increase until 2020 compared to 1995 (reference year), it always requires more and more stringent measures to achieve the same goal. This is an external factor not linked to the efforts made.

As far as benefits are concerned, they are included in the more general goal of the reduction of damages and not quantified separately for this measure.

- In the Loire strategy, this measure is part of the “basic set of measures” considered in the comparison of scenarios. It has to be combined with measures reducing the risk of breach in dykes and levees and improving the local protection of most exposed stakes.

As it is estimated that damages to economic activities would account for ~60% of all damages, whatever the return period considered, efforts for reducing damages should be made in this sector in priority. A detailed methodology has been developed to this purpose and experiments have been made: diagnosis is carried out in companies in order to identify stakes

exposed to different levels of water, then measures for the reduction of vulnerability are proposed. The idea is to develop a self-diagnosis toolbox.

- In the Saône basin, a very voluntary approach is planned. Indeed, it is intended to subsidise diagnosis of vulnerability in houses and in professional buildings and farms. The goal is to ensure up to 1000 € grant for residential properties and up to 2500 € for non residential ones. This measure shall benefit to 95 companies, shops and services, to 35 farms and to 520 houses.

On the basis of diagnosis, investment costs for the recommended individual measures of reduction of vulnerability would also be subsidised. Following mean cost for such measures have been estimated to calculate the necessary budget: 20000€/professional building; 12000€/house. Given this, it is intended to ensure 60% subsidies for the works (adaptation of buildings and machines, etc.). Altogether this measure shall cost 9,6 M€ i.e. 25% of the estimated cost of the action plan (5 years times).

- In the Vidourle action plan, another specific and original approach is developed. First, it is planned to relocate most exposed stakes, but this action is widely depending on the possibility to benefit from a national financial scheme for relocation of buildings exposed to natural hazards. In practice, as resources are limited, conditions for use are restrictive and complex. This is why a local contribution would be needed. On the basis of 40 houses, planned expense amount to 75000€/house i.e. between 40 and 60% of the cost of a house.

As for the Saône action plan, it is also proposed to identify areas at stake in order to design measures for reducing vulnerability of houses. Such programmes would include identification of required measures and subsidies to private owners during a limited period (3 to 4 years) so that houses are secured in the short-term.

Third, this measure includes a specific action towards farmers. In fact, concertation with farmers started right after the 2002 flood in a informal way. It is planned to adapt activities in flood prone areas: re-location of some activities in different areas less exposed to flood risk and adaptation of cultural methods taking into account the flood hazard. A detailed mapping is needed in order to characterise existing activities (e.g. lot of vineyards) and consider their respective constraints before starting relocation. The action plan only integrates indirect costs for such action, i.e. human resources required to organise this process, inform and negotiate with farmers, etc.

4.5- Emergency measures

This last category concerns the actual implementation of an emergency plan in the event of a flood. Despite forecasting and early warning systems, floods will always remain unpredictable to a degree. Neither flood protection nor prevention measures can guarantee absolute safety of lives and property, so that a residual risk will always remain. To deal with this residual risk, emergency and disaster planning needs to be in place to be able to react swiftly in case of extreme flooding events, to ensure information flows remain intact (providing real-time information); and effective coordination and cooperation structures.

- Emergency measures aim, above all, to **prevent casualties** (e.g. through evacuation plans and rescue services), but also to **protect livestock and movable assets** of cultural or commercial value. Next to evacuation, emergency measures also comprise flood fighting through temporary structures.
- Next to the protection of people and property, emergency measures also need to consider **environmental effects** that may arise through the flooding of industrial sites or wastewater treatment plants, and should comprise e.g. the removal of hazardous substances.³¹

³¹ See also [FLM03]

By their nature, emergency response measures are targeted at dealing with the residual risk that is not covered by protection and prevention measures. Hence, they need to consider also worst case scenarios where other measures fail, e.g. dam or dyke breaks.

Emergency measures are closely related to information measures, and need to be integrated with these. This includes e.g. providing information on self-help and rescue measures in case of floods.

Emergency measures are mostly in the responsibility of civil protection organisations, and are often organised on the local or communal level. In contrast to other flood risk management activities, there is an obligation (moral, legal or political) to carry out emergency measures, which means that they are not subject to weighing and trade-offs in the same way as prevention and protection measures are.

Three key factors are identified as determining for the quality of response [FLP26]:

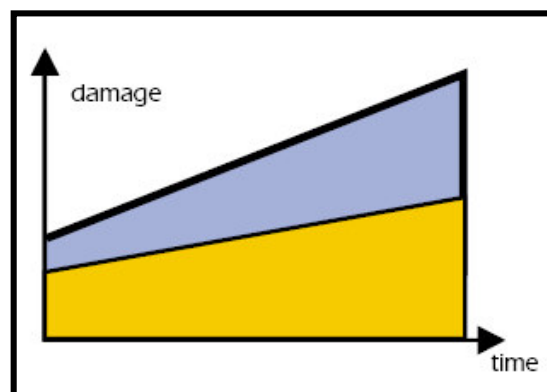
- time taken for assistance to arrive after or during event. Some demonstrating elements are detailed below
- amount of response i.e. the number of people assisting will probably affect the degree of response, if not the quality. Yet, this aspect is widely undocumented.
- response quality, including long-term response systems. Focus groups demonstrated that victims expect a lot of support from public authorities, not only in the short term: it generally takes very long time to recover from a flood both from a practical and financial point of view (e.g. deal with insurance companies) and from a human point of view (e.g. psychological recovery) [FLD25]. As for the amount of response, this aspect is hardly documented and is not taken into account in action plans, maybe because it is considered as an aspect of civil protection, not of flood policy.

4.5.1- Implementation of the emergency plans

Importance of human factors before / during crisis may have as much impact on consequences as the type of flood (duration, depth...):

- vulnerability is fully created by human activities
- combination of experience (positive: cf. Meuse [FLM13]) and of stress (negative: cf. South-East of France [FLD14]) when flood occur several times in a row in the same area

Though benefits of preparedness are difficult to quantify, trend may be described as follows: blue part illustrates the damage potential avoided thanks to preparedness.



Source: [FLM12]

Based on experience in Nîmes (F, 1998) it is possible to identify 3 successive phases during which significant efforts may be done in order to reduce direct and indirect damages [FLD26]:

- the crisis itself, a rather short period during which the affected community has to ensure its survival. Efficient organisation of disaster relief is the key at this stage.

- the post-crisis period during which measures taken aim at ensuring a basic functioning of the institutions: clearing of the accesses, setting of temporary replacement structures for supply, etc. At this time, affected companies are unable to produce and carry out their activity. Emergency aid has to be mobilised.
- a period of rehabilitation and reconstruction: urban fabric reorganises, companies progressively restart their activity, etc. Specific financial aid is then most needed: advance of cash, rescheduling of reimbursements, low-interest loans, etc.

The cost of activating emergency services during and after a flood event can be considerable and should be included in the evaluation process. As an example, in UK, emergency service costs are estimated at 10,7% of direct damages to residential and non-residential properties [FLD12].

In practice, among all actions plans considered in the project, only that for the Loire has formally integrated measures dealing with crisis and post-crisis periods [FLP11]. These measures are distinct from first aid and rescue actions and aim at reducing damages:

- by organising control of dykes, levees, reservoirs and all flood protection works in order to anticipate possible breaches;
- by ensuring that evacuated people don't go back too early to their homes and that economic activities restart in safe conditions (risk for the environment, electric risk...)
- by organising immediate measures, in particular in factories and most sensible activities, such as removal of some machines. Remove them from the flood in the first hours may ensure significant reduction of damages.

In fact, as the management of these periods relies very much on civil security, it is not formally included in the plan. At best, action plans integrate explicit measures such as the preparation of evacuation, the elaboration of road plan to regulate traffic in case of flood, etc. [FLP11][FLM36].

Yet, post-crisis it is not only a matter of ensuring immediate relief, different types of support have to be planned for these different periods. Some effects of the flood appear in the medium or even long term; adequate response has to be organised.

Flooded people expect much more support from public authorities as well as practical assistance. Recovery process may be very much affected by the conditions under which people manage to cope with several problems. The situation is indeed stressful as they live in poor material conditions and this is made worse as they have to organise with loss adjusters, insurance and building companies, etc. at the same time. Victims identify this as a key factor contributing to the recovery process, and in many cases lost confidence in public authorities [FLD25].

4.5.2- Post event analyses

Following flood events, it is important to organise post event analyses, for several reasons [FLD26][FLP22]:

- it provides information on the consequences, in particular the level and types of damages: this is of course useful locally and immediately for indemnification purposes for instance. It is also useful at wider scale as the collection and gathering of such data helps estimating the potential consequences of floods and better tailoring dedicated policies
- it gives the opportunity to analyse the way in which the crisis and post-crisis periods have been managed and to identify possibilities for improvements
- it helps designing (for the future) measures targeting indirect damages that had not been anticipated. E.g. practical measures for allowing companies to restart activity as soon as

possible (provision of computers, *ex-ante* organisation of the protection of most vulnerable electronic information such as lists of clients...)

- it also plays a psychological role: interviews with flooded people revealed that, even several months after the flood, they need to talk about the event, their feelings, their problems, etc. [FLD25][FLD27][FLP26]

In order to get the most out of these analyses, it is important to use common methodologies: this will ensure homogeneity and comparability of data collected for instance. An extensive research has been done in France to this respect, aiming at providing a practical tool for the identification and appraisal of all types of damages [FLD08]. It proposes detailed lists of damages and of indicators (monetary or not) to be used for appraisal, that are certainly transferable in other national contexts as the same types of damages may occur everywhere and as their quantification may be made in the same terms.

Still, a fundamental aspect is the identification of the sources of information: relevant data is highly sparse among several institutions and actors, both public and private, both at local and regional or national level, etc. This is of course very much linked to the national organisation.

From a general point of view, it is very useful to identify all these sources of information prior to events as it optimises the quality of the post event analyses: it is indeed a common statement that collection of information in such circumstances is very difficult. Such a measure may be part of an action plan, under the post-crisis chapter.

Part 5- The use of scenarios in flood management: the examples of selected river basins

5.1- The Role and Relevance of Scenarios in Flood Risk Management

On a general level, different approaches are available to deal with the threat of floods: strategies for flood risk management can follow a protective approach, a preventive approach, an informative approach, or an approach that focuses on emergency measures. These are not mutually exclusive – in practice, any strategy will necessarily involve a combination of the different approaches. Pure strategies, which focus exclusively on one approach and leave out all others, are not observed in practice.

Brouwer and Ek (2004) argue that in recent years, the expected impacts of climate change, sea level rise and land subsidence have led to a re-thinking of flood risk management [FLE23]. Confronted with these changing pressures, the long-term sustainability of traditional technical engineering approaches (including strengthening and heightening of dikes) has become increasingly questionable. Rather, Dutch flood management policy has tended to focus on alternative ways to deal with the risk of floods, such as land use changes and floodplain restoration. This new approach to flooding uses the natural dynamics and resilience of water systems as a means of reducing the long-term risks and damages associated with flooding. Similar trends can also be observed in other European countries. The need for such a paradigm shift from defensive action to management of the risk and living with floods is also emphasised in the 2003 best practice document of the European core group on flood protection of the Water Directors [FLM03]. The document also claims that non-structural measures tend to be more efficient and more sustainable solutions in the long term, and should therefore be enhanced.

Flood risk management strategies can be described as a combination of individual measures. These measures, as described in the fiches in the previous chapters, can be attributed to the different approaches to flood risk management. Depending on whether greater weight is given to preventive, protective, informative or emergency measures, the resulting strategy would fall into either category.

A scenario can be described as a strategy put into context: scenarios help to assess the impact of a particular strategy applied in a particular river basin. To this end, scenarios typically consider a time frame of several years or even decades, and model or describe the development of influencing factors as well as policy responses and their impacts. Scenarios should thus involve information on driving forces (e.g. climate change, demography, land use, economic development), pressures (increase in precipitation, built-up area in flood plains), state (occurrence and intensity of flooding events), impact (damage caused by flooding events) and responses (policy measures). At the same time, scenarios should not be mistaken for predictions or forecasts: rather, they are coherent and plausible stories of how human and environmental systems could evolve over time, necessarily involving a great deal of uncertainty.

The actual measures that would need to be considered in a scenario are highly site-specific: not all measures are applicable in all river basins, and their costs and the benefits they deliver will be strongly influenced by the local conditions in the river basin. It is therefore not possible to construct meaningful scenarios that could be applied on a European level; at best, a general typology of approaches can be described that could then be developed into concrete scenarios at the river basin scale. The approach followed in this study was therefore to identify and survey the scenarios that have been used in the two river basins at the centre of this study (namely the Rhine and Loire), and where possible to derive some conclusions for the European policy process from this. For the third river basin considered in this study, the Vidourle, there was no information on whether any scenarios were used to plan and design flood risk management measures.

The following paragraphs outline information on three different types of scenarios, based on evidence from the Rhine and the Loire. These are:

- A “do nothing” / business as usual scenario, assessing what would occur if no further action were taken and thereby establishing the baseline for the analysis;
- An “information and risk mapping” scenario, which consists of an improved information policy based on a basin wide flood risk map;
- An “action plan” scenario, which considers the basin wide development and implementation of action plans to co-ordinate and improve flood risk management practices.

These three scenarios were chosen with reference to the further policy development on the European level, where these approaches are expected to play a significant role, as described also in the 2004 Commission Communication “Flood risk management: Flood prevention, protection and mitigation” [FLP03].

5.2- Evidence from the Rhine and Loire

The situation at the Rhine and Loire regarding the construction and use of scenarios is inconclusive.

- At the **Loire**, the *Equipe Pluridisciplinaire Plan Loire Grandeur Nature* (hereafter *Equipe*) developed five scenarios in order to assess the potential damage and the impact of measures [FLP11]. The baseline scenario was in fact not defined as the “do-nothing option”, but rather consisted in a set of basic measures that were to be implemented in any case, and was consequently included in all scenarios. The baseline scenario was then complemented by four action scenarios. In addition to the basic measures, these scenarios consisted of different combinations of measures. Under each scenario, measures were chosen in order to address all three pillars for a flood strategy identify by the *Equipe*, i.e. prediction measures, (non-structural) prevention measures, and (structural) protection measures. However, while prediction, prevention and protection measures are all included in the basic measures that constitute the baseline scenario, the additional scenarios only differ in terms of the additional protection measures chosen, with scenario 1 consisting of the basic measures and the erection of additional dykes, scenario 2 consisting of the basic measures and additional weirs, scenario 3 comprising the basic measures and additional measures to reduce peak run-off (construction of the *Le Veudre* reservoir), and scenario 4 combining the scenarios 1 and 3. The five scenarios were then evaluated under three different hypothesis (related to the probability of dyke failures and groundwater upflow) and for four different return periods (HQ₅₀ to HQ₅₀₀). The analysis revealed that the avoided damage under scenario 2 was minuscule, but quite substantial for scenarios 1 (4 – 12 million Euro) and 3 (4 – 8 million Euro). In the end, scenario 4 was selected as the recommended course of action, which combined the highest costs and the highest avoided damage (8 – 17 million Euro p.a.). In addition to the analysis conducted by the *Equipe*, a larger-scale CBA was carried out for the Loire-Bretagne district [FLE22]. This CBA compared a no-action scenario (the “do-nothing option”) with one action scenario, which consisted of the implementation of the proposed district management plan, SDAGE Loire-Bretagne.. Detailed calculations were carried out for five representative towns in the basin, and for four different land use types (agricultural areas, densely populated settlement areas, sparsely populated settlement areas, and industrial areas). The results were then extrapolated to the rest of the Loire-Bretagne basin.
- For the **Rhine**, elaborated scenarios do not exist on the basin level. For the main course of the river, the damage atlas compiled by the Rhine Commission provides some building blocks for scenarios but does not present scenarios proper. As for the local flood management action plans that have been drawn up for some tributaries of the Rhine, these make use of scenario analysis to a different degree. From an academic context, a good example of scenario-based analysis is provided by Brouwer and Ek (2004) [FLE23], who compare the outcomes of three different strategies (sets of measures) to improve flood protection in the Rhine Delta. This is done over a time period of 50 years, incorporating predictions on the additional pressures

imposed by climate change. As part of a CBA, they compare three different sets of measures targeted at widening and deepening of flood plains, providing extra space for rivers and adding new watercourses. These measures are assessed over the medium (2015) to long term (2050). Through a Multi-Criteria-Analysis, the authors compare the impacts of this “progressive” scenario of “living with rivers” with a more conservative scenario, comprising structural protection measures like dyke heightening. The effects under both scenarios are confronted with a “do-nothing” baseline scenario.

A general caveat concerns the transferability of scenario results. Where scenarios are used, they are defined by locally appropriate measures, e.g. to compare the impact of a specific, proposed action plan with a no-action scenario. There are few examples where scenarios have been used to design the action plan itself, or to compare different ways of reaching a target. The action plans themselves would normally comprise elements of flood protection and prevention as well as (albeit to a lesser degree) information and emergency measures. In this sense, drawing generalised conclusions from the use of scenarios – along the lines of comparing a protection, a prevention and an information scenario – is difficult.

Also, where scenarios are used, they typically describe the impact of proposed measures for one or more specified flooding events (e.g. a centennial flood / HQ₁₀₀). Assessments of how drivers, pressures and impacts will evolve over time, such as climate change leading to a higher frequency and intensity of floods, or changes in the damage potential due to economic and demographic factors, are either not included at all, or are at least not quantified. In this sense, most scenarios described in the flood action plans would not qualify as scenarios in a narrow sense.

An alternative would be to follow a bottom-up approach to scenario development, whereby specific measures would be combined to construct scenarios for the Rhine and the Loire. However, the available information on the measures conducted at the two rivers is too scarce, too patchy and too inconsistent to support the construction of proper scenarios. To this end, gathering of primary information would be necessary, supported by hydrologic, climatic and macroeconomic modelling.

The following section discusses the situation as regards scenarios in the Loire and Rhine basins in greater detail.

5.3- “Do nothing” scenario

For the scenario analysis carried out at the Loire by the *Equipe* [FLP11], the baseline scenario is not so much a “do nothing” scenario, but rather a scenario that includes all measures that are commonly agreed and will be implemented in any case, irrespective of the outcome of the analysis. These measures comprise information / prediction measures (flood forecasting and early warning systems, public awareness on best practices), prevention measures (limiting the use of floodplains), protection measures (measures to reduce the impact of flooding, maintenance of dykes) and emergency measures. The baseline scenario was described in terms of the costs (capital costs and annual operation costs), the average (residual) damage after measures have been taken, and the number of affected people and number of affected industrial sites for different return periods. Benefits for the baseline scenario were not assessed. Instead, the analysis calculated the additional gain from further measures in comparison to the baseline.

For the CBA carried out in the Loire-Bretagne district [FLE22], the “do-nothing” scenario measures the expected impact of a centennial flood, if development in flood-prone areas continues unchecked. Of the total potential damage of Euro 2.5 – 3.6 billion calculated for the Loire-Bretagne district, around 60% were due to damages in urban areas. The scenario was not extrapolated into the future, but does provide illustrative calculations of how the damage potential in two cities (Bourges and Argenton sur Creuse) would evolve if urban development in flood-prone areas was allowed to continue. In the case of Bourges, even a modest development of 10% would almost double the damage potential.

At the Rhine, the situation regarding the use of scenarios is more complex. The ICPR has produced an atlas of potential damages that covers the river course (without tributaries) [FLD03]. The potential damage is presented for five sections of the Rhine (from the High Rhine to the Delta), and desegregated into the categories settlement, industry and traffic and agriculture. The estimated total damage potential amounts to Euro 165 billion, of which 83% would be due to damage to settlements. In terms of spatial distribution, just below 80% of the damage potential is located in the Rhine Delta. The damage atlas in itself, however, does not represent a “do-nothing” scenario: as while it shows the maximal damage that could occur on each section of the Rhine, it does not provide a realistic scenario for a certain runoff, because to issues like the retention capacity of flooded areas, the possibility of dyke breaks or the impact that flooding of one area will have on downstream areas. Indeed, it is underlined in the atlas that the total damage could not occur during one single event, but that the indications are only realistic for the river sections. Taking the total potential damage as a baseline for the “do nothing” scenario would significantly overstate the expected damage for any particular event, as it would be most unlikely that the worst case should occur in all parts of the basin simultaneously. Rather, if one part of the basin suffers from severe flooding it is to be expected that the flood will be correspondingly less severe in downstream areas. The damage atlas does, however, provide a central building block for the construction of scenarios for river sections or for the river as a whole.

In addition, information exists on a local to regional scale at the Rhine, e.g. scenarios for the City of Cologne [FLD39] or for some tributaries of the Rhine (e.g. the Lippe, [FLM72]). In these cases, the no-action scenario is used as a baseline against which the proposed actions are measured. Action plans for other tributaries such as the Nahe [FLM50] do not specify a baseline. Illustrative damage or casualty figures from past flooding events are used to underline the necessity of action, but it is not discussed how large the damage resulting from a future flood would be, or how far these impacts could be reduced by the proposed measures.

5.4- Elements for Scenarios towards improved flood management

As noted above, a construction of elaborated scenarios describing costs and benefits is not possible with the available information. Instead, the analysis will be based on what has been done at the Rhine and the Loire, and describe additional elements that could or should be included in a scenario.

5.4.1- Use of information measures and flood risk mapping

Better information on flood risk serves two main purposes:

- First, it helps to raise awareness of flood risks among the wider public, in order to support both efficient responses once the flood is underway, as well as self-protection measures taken in preparation of a flood.
- Secondly, information provision (and flood risk mapping in particular) has a key role in supporting an optimal policy response to flood threats, to guide decision makers in choosing efficient strategies and implementing them in the most cost-effective way.

In the following, both aspects are discussed for information measures in general, and for flood risk mapping in particular.

i- Information measures

Regarding the first aspect, awareness of flood risks and knowledge of possible responses is key to minimising material damage and losses of lives. There is clear evidence that the damage caused by floods tends to be much higher if they only occur at long intervals, whereas the cost of recurring flooding events is relatively lower. In the Netherlands for instance, the flood of 1995 was far less damaging than the one that took place in 1993, despite the fact that the two events were comparable in their magnitude. The reason is that whereas the 1993 flood took the affected people by surprise, the

information and awareness was much better in 1995. Having seen where the water can go, and how fast it can come, people were much better prepared for the second flood, and in particular knew better which valuables to save.

This points to the crucial relation between information and awareness of the risks imposed by floods – ultimately, awareness of flood risks is decisive for reducing the impacts in an emergency situation. Information measures can help to create such awareness, and to maintain it over time. Experience shows that the awareness of flood risks decreases rapidly after a flood has taken place, which implies that repeated information measures are necessary to keep awareness levels of the risks and appropriate responses high. A different type of informational measures is targeted at individual, small-scale protection measures that can be carried out at little or no extra costs; this concerns e.g. the storage of valuable or dangerous items.

While such information and awareness measures are developed and implemented over a longer time period, irrespective of a particular flooding event, a different category of information measures concerns the early warning measures in the case of an actual flooding event. Every minute of increased reaction time will decrease the damage caused, as it gives the affected population the needed time to save valuable items and to carry out ad-hoc protection measures. As an illustrative indication, it has been estimated in the case of the Rhône that extending the warning time to more than 48 hours could reduce the damage by 20 to 40 per cent [FLM29].

At the Loire, the cost of developing and implementing an improved modelling tool combined with weather forecasts as well as early warning procedures was estimated at EUR 7.6 million for setting up the system, and EUR 1.2 million annual running costs. In the Saône-Doubs basin, the cost of improving existing flood warning system and improving the information flow was estimated at EUR 0.7 million for 28 municipalities affected (i.e. EUR 25,000 per municipality on average) [INFb-03]. In addition, expenditure for several information measures targeted at the general public added up to EUR 0.5 million over a 5-year period [INFc-02]. The scenario analysis conducted at the Loire, however, does not shed any light on the expected impact of information measures in comparison to other measures: the information measures are included in the set of basic measures that is implemented under each scenario.

ii- Flood risk mapping

Flood risk mapping can be useful to support such awareness raising by visualising the individual risk of being affected by a flood, especially in areas that have not suffered from a flooding event for some time. Moreover, it is key to planning and targeting effective flood risk management strategies.

Assessing the costs and benefits of flood risk mapping is a more complex task than it is for physical flood protection or prevention measures: flood risk maps (like all information measures) by themselves do not have any direct impact on the occurrence of floods or the damage that they cause. Their role is to inform decisions in order to ensure that optimal responses are being taken. Their benefits are thus largely indirect benefits, consisting of better decisions being taken. At the same time, information measures are relatively inexpensive.

Thus, the ICPR's action plan for the Rhine [FLP09] foresees expenses for improved precautionary planning measures, including risk mapping, of EUR 13 million between 1998-2000, EUR 38 million between 1998-2005 and EUR 60 million until 2020. The cost of measures to extend the early warning period are even lower at EUR 4 million (EUR 12 million / EUR 12 million) respectively for the different periods [INFb-01]. Taken together, the cost of flood risk mapping and information measures corresponds to about 1 per cent of the total cost of flood management measures foreseen in the action plan. In relation to the potentially affected population along the Rhine (10 million people [FLD03]), the costs are between 1 and 7 EUR per person for the different time periods.

5.4.2- Preparation and implementation of an action plan on floods per basin

The costs and benefits of having or not having an action plan are less obvious than they are for specific flood protection or prevention measures. Indeed, the costs and benefits of implementing an action plan will be determined by the type of measures selected for the plan, and the dimension / scale in which they are implemented. The cost of establishing the action plan itself is only minor. On the benefit side, the immediate use of having an action plan on the local or regional level is widely admitted: no coherent policy is possible without an overall approach that ensures flood management measures are consistent and chosen to maximise benefits (whether monetary or otherwise). Yet, quantification of the benefits brought by an action plan is difficult.

For a basin-wide action plan, the added value mainly stems from the improved co-ordination of the different levels of decision making (from the local level up to transboundary co-ordination in international river basins). The challenge here is to arrive at an approach that is efficient not only at the scale of a sub-basin or a region, but at the scale of the entire river basin.

In this regard, some insights can be gained from the case of the Rhône basin in France [FLM29]. The upper Rhône is located in the Alps, where it is in a fairly natural state. The hydromorphology of the middle Rhône, by contrast, is modified in many instances. Additionally, the middle Rhône is used intensively by industry and agriculture located along the river. The lower Rhône is a delta area characterised by a unique natural environment. This means that the three sections are very different in terms of the types of floods that can occur, the uses of the river and the economic activity near the river, the associated damage potential, the presence of morphological changes to the river etc. The Rhône experienced severe floods in 1993 and 1994, then again in 2003 (with a damage of Euro 844 million in the latter case). Deficits in the organisation for flood management were identified as a key factor that contributed to the high damage suffered [FLM29]. Indeed, the different actors were not co-ordinated at basin scale (i.e. data gathering, warning systems, operation of dams and reservoirs, monitoring of dykes, evacuation and emergency measures etc.). In particular, the poor condition of several dikes and resulting breaches posed a problem in the course of 2003. Lack of co-ordination aggravated this: a number of different actors were involved, but there was no centralised overall management of actions, neither was there a superior authority with the competence to instruct other actors [FLM72]. While it is impossible to quantify the contribution of these shortcomings to the total damage, and while there were several other factors contributing to the severity of consequences, it can safely be concluded that the lack of preparation, co-ordination and established routines clearly contributed to the level of damages.

The benefit of a flood action plan should also be considered across spatial scales. In most instances, flood action plans exist on a local level. However these should also be integrated and interconnected in a basin-wide action plan. The added value of such a plan lies in the optimisation of individual measures planned at different points in the basin, and in the co-ordination of the approaches followed in different parts of the basin. This ensures the consistency of the measures implemented in different parts of the basin and creates a common forum in which the local authorities and governments inside a river basin can agree on a common path of action, possibly even to negotiate financial burden sharing for the measures to be taken.

At the same time, the benefit and the potential impact of a flood action plan at the basin level will largely be determined by the political realities, especially in large international river basins. In case of high stakes and vested interests, the decision on a strategy at the river basin scale will not be based exclusively, or even primarily, on the criterion of economic efficiency. Instead, a flood action plan is more likely to be the negotiated results of a political discussion process, reflecting power relations and the different countries' political "willingness to pay".

5.5- Summary and outlook on the use of scenarios

In summary, it can be noted that at the river basin scale, the use of scenarios in defining flood risk management strategies is less common than one could have expected. Where scenarios are employed, they are normally used to determine the impact of some predefined set of measures in comparison to a

baseline scenario (“do-nothing-option”). There are few cases, such as the Loire or the Somme, where this is done for more than two scenarios. Other cases, such as the Loire-Bretagne area, the Lippe or the Cologne Rhine, merely compare one action scenario with one non-action scenario. The strategies underlying the action scenario themselves are not developed on the basis of a scenario analysis, but rather based on expert judgement.

In some cases, a greater number of scenarios has been developed.

- In the case of the Loire, five different scenarios were assessed [FLP11], including one baseline scenario and four action scenarios. The action scenarios were evaluated in terms of their costs and the benefits (avoided damage) in relation to the baseline scenario. The analysis does not provide benefit-cost ratio for the different scenarios, but presents costs and (relative) benefits in desegregated form instead.
- At the Somme seven options are compared with the aim of keeping the lower Somme navigable and enabling access to different ports [FLD09]. While the document refers to them as scenarios, they are in fact little more than options to limit or prevent sedimentation. However, this comparison of different options itself is not included in a Cost-Benefit Analysis. Instead, a pre-screening takes place to determine the most feasible / effective option, and the Benefit-Cost ratio is subsequently assessed for the selected option only.

In general, where different scenarios are developed, these tend to be fairly close to each other, and would often consist of different combinations of similar measures. Extreme scenarios, such as a comparison of a “pure” protection strategy with a “pure” prevention strategy, are hardly found (with [FLE23] as one exception). In the case of the Loire, while the scenarios differ substantially in terms of costs and expected impacts, they differ less in terms of the measures included in different scenarios: the scenarios differ in terms of which protection measures are included or not, whereas prevention, information and emergency measures are included in the basic set of measures that is implemented under each scenario. The observation that the compared scenarios are fairly similar may be due to the fact that the scenarios are pre-selected based on expert recommendations or negotiations, eliminating extreme scenarios as impracticable.

The term “scenario” is used differently by different authors. Some authors describe scenarios in terms of the return period of a flood: usually, these either refer to a centennial flood (HQ₁₀₀), or to some “worst-case scenario” defined e.g. as the worst flood in history. However, this does not constitute a scenario as it is understood in this study, i.e. a description / modelling of alternative paths of action and their effect on floods and flood damages. Very few authors (e.g. [FLE23]) incorporate an assessment of possible future states of the world, describing changes in socio-economic and ecological drivers, pressures and impacts, and their effect on the occurrence and intensity of floods.

One aspect of scenarios that would be of particular relevance for comparing different flood management strategies is the development of the damage potential in an area (i.e. the value of buildings, infrastructure and movable goods in the risk area). One objective of flood risk management is to limit or reduce the damage potential, in the case of the Rhine action plan by 10% until 2005 and by 25% until 2020 (compared to the base year 1995) [FLP09]. The development of the damage potential will of course be driven by underlying socio-economic and demographic trends (income growth, urbanisation patterns etc.), but there is also some evidence that flood management measures themselves may have an impact on the damage potential. Structural flood protection measures such as raised dikes may encourage development in the protected areas that were previously considered as unsuitable for development due to the flooding risk. By attracting more values into the protected area, this may effectively counteract the flood management objective of reducing damage potential. It may even result in a self-reinforcing pattern where raising dikes leads to higher values in the protected areas, which means that dikes have to be raised further etc. Wind (1999) argues that such an effect can be observed in the Netherlands [FLP28].

Part 6- Interpretation and recommendations

6.1- The current use of economic assessment tools at the Rhine and the Loire

6.1.1- The use of economic assessment methods

Some Member States, especially the UK, the Netherlands and also Germany, have ample experience with the use of Cost-Benefit Analysis in the selection, design and implementation of flood management measures. The integration of CBAs into flood risk management policies is probably furthest developed in the UK, where central government funding for flood management measures is conditional on a favourable benefit/cost-ratio. In principle, the methodology for CBAs can be considered as sufficiently developed and established to provide useful inputs into policy formulation. Problems that limit the application of CBA are more related to the availability of data, to the insensitivity of CBAs towards certain types of impacts, the difficulty of expressing certain impacts in monetary terms, and its limited openness to public participation and stakeholder involvement. These factors limit the scope where CBA can be usefully applied. In some of the countries, assessment practice has therefore gone beyond a pure CBA, complementing the analysis with qualitative elements or using a Multi-Criteria Analysis instead. The following general observations on the use of CBA in flood risk management are more applicable to the countries that have moved beyond CBA, and possibly less relevant for those countries that have considerable experience with the use of CBA in flood risk management (esp. the UK).

- In practice, CBA is mostly used for the assessment of individual, well-specified flood management measures or the combination of measures. For such single, locally effective measures, data on the expected impact is fairly well documented, and CBA provides a reliable assessment tool. On higher aggregation levels, by contrast, CBA is not normally applied, neither on a spatially aggregated level (national level or basin-wide), nor on a more aggregated level of political decision making (e.g. on the strategic decision level, including the trade-off between protection, prevention, information and emergency measures). Documents like the Rhine Action Plan [FLP09] or the Plan Loire Grandeur Nature [FLP10] do refer to the cost of non-action or to the economic implications of one or another approach, and support these references with quantified evidence. However, such approaches should be regarded as a political argumentation supported by economic figures rather than a CBA in the proper sense.
- In principle, it would be possible to “upscale” a CBA to higher levels of spatial or political aggregation (or both). The main problem associated with the upscaling is that the uncertainty of the results increases substantially if the analysis shifts to a more aggregated level: there are multiple interactions between different measures that need to be taken into account, assumptions need to be made about the behaviour of different actors, etc. At some point, the uncertainty may even become unmanageable, preventing definite conclusions to be drawn from the analysis. In order to come to more substantiated forms of analysis at the basin level, the economic analysis would need to be closely integrated with a hydrological modelling at the basin scale, as well as developing comprehensive scenarios of socio-economic driving forces and the behaviour of individual actors.
- Faced with these uncertainties, what can be observed in practice is that decisions at the strategic level are often the result of political bargaining, e.g. by specifying a certain protection level that needs to be guaranteed at any cost (expressed as return period, often HQ₁₀₀). Although such decisions may be informed by economic considerations, the protection level itself is not the result of an economic trade-off.

- In terms of the measures considered, CBAs tend to be applied mainly to the analysis and comparison of structural-technical flood protection measures. Non-structural flood protection measures and flood prevention measures, such as the revitalisation of flood plains, are not considered as widely, mainly because the impacts of such measures are more difficult to quantify [FLM79].
- Completeness and coverage of the analysis differs, especially in terms of the benefits considered. Most CBAs consider the avoided damage to material assets as the main benefit category. For this category, there is either historical evidence or calculated data, e.g. in the damage atlas that has been compiled for the Rhine [FLD03]. Such information is often compiled in the form of databases, e.g. in the case of the UK through the Flood Hazard Research Centre (FHRC) at Middlesex University. While such databases are essential for a CBA, they can be costly to implement and require regular updating.
- Whereas estimates of avoided damage are regularly covered in CBAs on flood management, the environmental benefits of measures (such as the role of floodplains as a natural habitat) are rarely considered in such analyses. This is also due to the fact that most CBAs focus on structural flood protection measures, which create fewer environmental benefits than some of the non-structural measures. In general, wetlands (among which floodplains) are among the most extensively researched biomes from an environmental valuation perspective. Among the ecosystem services provided by floodplains, flood retention is one of the most important factors (along with biodiversity support or nutrient removal). The comparatively solid data situation for riparian wetlands means that the economic value of the ecosystem services they provide can be assessed, at least as an approximation, by transferring the results of existing studies (benefits transfer). Brouwer and Ek (2004) demonstrate that including estimates of the environmental benefit may have a substantial effect on the outcome of an analysis [FLE23]. In the study case considered, including the ecosystem services provided by wetlands tilts the balance in favour of the proposed set of measures, which comprise a widening of floodplains.
- Next to environmental effects, a further category that is difficult to reflect in economic terms – and consequently often excluded from CBAs – are the intangible damages, e.g. impacts that flood management measures may have on the landscape and amenity values of a river, or on the stress and anxiety of people living in flood-prone areas. While such effects can be valued in principle (e.g. through contingent valuation or hedonic pricing studies), they would need to be assessed through costly and time-consuming primary valuation studies. An alternative that is often evoked for the valuation of intangible and environmental effects, the transfer of results from other studies through a so-called benefits transfer, is limited by the narrow data base. It remains to be assessed through case studies in how far such impacts are relevant. For the current practice, it appears that the cost and benefit categories included in a CBA are not necessarily the most significant ones, but rather those that are easiest to value in monetary terms.

Partly because of these limitations, policy makers and stakeholders often perceive CBAs as a mechanistic black box that prevents all discussion by prescribing a particular course of action, which is blind to certain types of impacts, and which feigns a level of precision and a clarity of judgements that is not supported by reality (see also [FLE06]).³² Partly as a reaction to these criticisms, it was decided in some basins to extend the coverage of CBAs beyond purely monetary costs and benefits. In this way, qualitative and non-monetary quantitative elements are also taken up in the analysis in such instances where monetary valuation is not available or not applicable. Such approaches, which effectively complement a CBA with elements of a Multi-Criteria Analysis (see below), can be found e.g. in France or in the Netherlands [FLD26]. Even though they cannot eradicate all of the uncertainties involved in a CBA, and may introduce new uncertainties, they do take up the most criticised aspects of CBAs.

³² Such criticisms may also be due to an inappropriate use of CBAs in political decision making – in fact, any economist would agree that CBAs are conducted in support of decision making, and not to replace it. This means that a decision maker does not have to implement the option with the highest benefit-cost ratio, if there is an overriding interest not to do so. But if she chooses against it, she will be forced to motivate her decision and thereby make the underlying trade-off explicit.

6.1.2- Other assessment methods

A **cost-effectiveness analysis (CEA)** seeks to find the best alternative activity, process, or intervention that minimises resource use to achieve a given result. CEAs are performed when the objectives of the public policy have been identified and the only remaining question is to find the least-cost option of achieving these objectives. In a CEA, the cost-effectiveness of a policy option is calculated by dividing the annualised costs of the option by physical benefit measures, such as kilometres of river length restored, centimetres of peak run-off “shaved off”, number of households protected etc. Different options that achieve the same objective are then compared based on their cost. CEA, therefore, does not ask, nor attempt to answer, whether the policy is justified, in the sense that its social benefits exceed its costs. CEA is sometimes used as a second-best option when a full-blown CBA would be desirable, but many benefits cannot easily be monetised. In flood management, a CEA would appear to be more suited for a “traditional” approach to flood management, whereby protection against given flood level has to be guaranteed irrespective of the benefits. CEA in this case may support the selection of the least-cost option for achieving this protection level. A CEA may also be a sufficient tool in cases where the benefits (in terms of potential damage) are so large that a building, an area or an installation needs to be protected at any cost.

A **Multi-Criteria Analysis (MCA)** is a structured approach used to determine overall preferences among alternative policy measures, where each policy measures may pursue several objectives. It is used to structure a policy problem in terms of possible policy alternatives and to assess each alternative under various criteria. A Multi-Criteria Analysis represents a more flexible approach than CBA or CEA to frame the issue and to structure the decision making process. Multi-Criteria Approaches are particularly relevant in cases where the effects of different options can be assessed, but where it is difficult to value them in monetary terms (see e.g. the IRMA-SPONGE project for an application to the case of floods [FLM58b]). They can also be applied in cases where only part of the benefits of a flood protection measure can be captured in monetary terms, and where it is expected that the non-monetised effects will be significant for the results of the analysis. An MCA remedies this problem by accommodating a range of social, environmental, technical, economic, and financial criteria, expressed either in monetary form, in quantitative non-monetary (physical) form, or in qualitative form, based on expert judgement or public participation.

A particular strength of MCA is that it can easily be integrated with participatory approaches in different stages of the decision making process, including the identification of options, information gathering and the definition of weights for the different criteria. Since the weight of the different criteria is not determined beforehand (as it is implicitly the case for a CBA, where all impacts are monetised), it provides for a transparent decision making process, where assumptions need to be explained to or discussed with stakeholders.

One setback of MCAs is that they are often be difficult to use for lay people. Most of them require an expert to explain how the method works, and to help users to define options, criteria and weights, as well as to choose an aggregation procedure. Also, although the use of an MCA partly avoids the problem of monetising all impacts, it still requires a significant amount of information. Finally, an MCA may find itself exposed to allegations of subjectivity if the user misuses the flexibility that an MCA provides.

A practical example for an applied MCA is provided by the UK, where decision on public grants / funding for flood protection measures is based on the Priority Scores of the measures. To calculate these scores, different factors are taken into account: these include the benefit-cost ratio of the scheme (which is assessed through a separate CBA), the number of households affected, the area of environmentally designated land and important heritage sites protected by the scheme, the level of social vulnerability for the area and the level of risk if the project was not implemented (e.g. floods with short warning times and high, fast flowing waters will have a higher risk score than floods for which long lead warning times are possible and do not pose a real risk to life). This provides an example of how cost-benefit considerations can be included as one (albeit central) criterion of a Multi-Criteria Analysis, but at the same time complemented by other, non-monetary factors.

6.2- Possibilities and limitations of an EU-wide extrapolation

Providing EU-wide evidence on the costs and benefits of flood protection measures is currently not possible. Such an exercise may also be of limited value for decision making: the transferability of results among basins, or even between different parts of the same basins, is limited by the fact that each river has its own characteristics, and that each flooding event is different. In qualitative terms, some specific lessons may be drawn that can be generalised to the river basin level and to other basins. However, this does not apply to the majority of quantitative results, which are highly site-specific.

- At present, it already presents a considerable challenge to integrate the available evidence on the basin level, in order to arrive at flood management strategies that are efficient on the basin scale. Once the methodological and data difficulties of this “upscaling” are addressed in a satisfactory way, the next step would be to compare experiences in different basins.
- At the same time, exchange of information by practitioners in different basins is valuable, not least since pressures such as climate change and land use changes are common to most basins and present similar challenges for flood risk management.
- In addition, it may be worthwhile to identify and describe a best-practice approach to the economic appraisal of flood management strategies. This comparison would not so much focus on the individual measures chosen, but rather on the process that is followed in the selection and prioritisation of measures.

In analysing the experience with economic assessment of flood risk management strategies, this study has placed particular emphasis on the experiences made in the Rhine and Loire basins. The question whether these two basins are representative for the European context as a whole cannot be answered with a simple yes or no, but some factors can be identified in favour or against.

Factors that would suggest that the basins are representative include the considerable size of the basins as well as their internal diversity in terms of hydromorphological conditions and economic uses. Furthermore, the Rhine has experienced a considerable number of floods, suggesting that past damages, potential impacts and future strategies are better researched and documented than in other basins. The Rhine is also exemplary (though perhaps not representative) with its long history and well-established institutional mechanisms for international co-operation and exchange.

However, the applicability of results obtained at the Rhine and the Loire to other cases is limited by the fact that many water-poor situations in Southern Europe and many small basins have other flood histories, where flash floods are expected to play a greater role. Both at the Rhine and the Loire, the focus is clearly more on static floods and measures to deal with these. Flash floods do occur in the uppermost parts of the Rhine and Loire basins, but are not considered in-depth in the analyses and strategies presented. For smaller basins, the issue of moving up and down the scales is also clearly less problematic.

In terms of economic expertise and experience, both Rhine and Loire can be considered as examples of good practice by European standards. While this study was not intended to provide a comprehensive overview of the use of economic approaches in flood risk management in Europe, a scan of the literature did not reveal any European river basins of comparable size where economic assessment would be significantly better developed. Although the UK has institutionalised procedures for integrating economic approaches into flood risk management decisions, these also tend to be more on the local level than basin-wide. In addition, river basins in the UK are generally smaller than the Loire and Rhine basins, which facilitates the use of economics, but limits the comparability with the Rhine and the Loire.

Both the Rhine and the Loire make use of economic assessment and appraisal of flood management strategies to some extent, although the integration of economic approaches into decision making could be developed further: both at the Rhine and the Loire, some estimates of the costs and benefits of flood risk management have been made, especially on the local level. However, these have not (yet) been developed into a systematic CBA on the basin level, ideally incorporating scenarios that allow a comparison of different ways of dealing with floods. Some further recommendations on the future development and use of economic assessment methods for flood risk management are described in the following chapter.

6.3- Recommendations

The results of this project described above shed some light on the possible or desirable role of economic issues in a European flood risk management strategy. The following recommendations for the integration of economic aspects into a European approach to flood risk management can be made:

- The case studies of the Rhine and the Loire demonstrate that specific solutions are required for each specific case. A meta-analysis of flood protection issues and approaches can identify common problems and issues, and identify common ways of dealing with them, but it cannot deliver common solutions in the sense of recommending a particular mix of measures. Also, the scope for transferring quantitative results on the costs and effects of measures is limited; such information can at best illustrate the lessons learned in one basin, and stimulate discussion in another basin.
- The potential for exchange and transfer of experiences will therefore be much larger on the level of procedural questions (how are measures selected and monitored, how are action plans developed and implemented etc.), than on the level of individual measures and their impacts. Thus, each river basin has to develop its own approach, depending on the stakeholders involved and adjusted to local circumstances.
- Still, the transfer of actual estimates on costs and damages can make sense for some types of costs and damages, and under certain conditions: for example, the calculations of damage potential in the Rhine damage atlas [FLD03] are partly based on German damage figures that have been transferred to the Netherlands and to France. Such a transfer of values is also relevant in the case of transferring valuation of environmental benefits. However, it needs to be ensured that the two sites between which values are transferred are sufficiently similar.
- Notwithstanding the caveat that specific solutions need to be found and implemented for each river basin, the category of information measures recommends itself as inexpensive yet effective throughout the basins considered. This concerns three types of measures in particular: first, flood risk mapping can serve as a basis for effective policy design, in order to allocate resources most efficiently. Secondly, flood prediction measures may extend warning times and thereby give people more time to react to an oncoming flood. Thirdly, information of the public on flood risks is necessary in order to keep awareness levels high and to inform about appropriate responses. For each of these measures, it has to be acknowledged that their impact is an indirect one. By providing information, they stimulate a certain behaviour, which may then reduce damages. However, also an indirect effect can be a very large effect: for instance, this is documented by the 1995 Meuse flood in the Netherlands, which caused far less damage than the comparable 1993 flood, mostly because actors were better informed, better prepared and more aware of the risk and possible responses. Regarding flood prediction measures and early warning, it has been estimated that increasing warning times to more than 48 hours may reduce damages by 20 to 40 per cent [FLM29]. Apart from their effectiveness, one main advantage of information measures is their relatively low cost. In comparison to protection and prevention measures, the cost of information measures is minuscule. In the Rhine Action Plan [FLM09], the cost of flood risk mapping and communication measures and the cost of flood forecasting and early warning systems together amounted to 72 million Euro, which is about 0.5 percent of the total cost of 12.3 billion Euro. At the Saône, the cost of flood forecasting and early warning systems and the cost of measures to promote public awareness on best practices was estimated at 1.073 million Euro, which corresponds to below 3% of the total cost of the action plan (36.8 million Euro).
- The study also revealed the benefits of having a basin-wide action plan specifying objectives and possible measures at the local level. Where such action plans have been developed, they do not only lay the foundation for an efficient flood management strategy. The process of developing the action plan is also conducive to the involvement of stakeholders and, in the case of transboundary basins, to enhancing international co-operation and exchange. Also, there is a case for negotiating and implementing flood action plans in quiet times, unrelated to a particular flooding event. While it is easier to mobilise funds for ambitious flood protection

measures in the wake of a major flood, such decisions tend to be taken under pressure, irrespective of cost-benefit considerations.

- The establishment of basin-wide action plans is in line with the objectives of the WFD, which calls for a harmonised and coherent approach at the river basin level, ensuring that selected combinations of measures are cost-effective at the basin scale. A possible role for the EU could be to ensure the use of coherent methodologies in different parts of the basin, and to facilitate the exchange of information and experiences both within and across basins. Another central task would be to establish co-ordination mechanisms for transboundary co-operation in those basins where such mechanisms are not in place already. This would especially concern countries that are not (yet) EU Member States.

Based on the Commission Communication “Flood risk management: Flood prevention, protection and mitigation” [FLP03], a Directive on flood risk management is currently under preparation. The European role in flood management is somewhat ambivalent given the fact that the EU has strong competencies in the field of water policy, but not so in the case of land use and spatial planning (which falls under the competence of the Member States or the regions). In view of this fact, the Commission takes the stance that the future Directive should be a “lean Directive”, which does not specify particular measures but rather supports a coherent approach in the Member States.

In this context, the Directive should specify the role, position and weight of economic appraisal in the decision making process. This role could range from economic assessments as a primary decision criterion (e.g. introducing a general cost-effectiveness requirement for all measures implemented under the Directive, including the establishment of action plans), to a minor role where overriding objectives are set a priori through social discourse (e.g. specifying that loss of human lives has to be avoided at any cost, or that a certain protection level should be guaranteed, and that economic appraisal comes in only after this has been ensured).³³

The forthcoming impact assessment of proposed action in the field of flood risk management will need to consider the indirect impact that EU measures (information, action plans) have on the actual flood management policies implemented on the local level. Information measures recommend themselves as relatively inexpensive tools, which are at the same time indispensable for sound and effective flood management strategies. Information measures targeted at the wider public can be highly effective and efficient if they succeed in motivating and educating actors to take appropriate responses in the case of a flood. Nonetheless, the effects of information measures on flood risk are only of an indirect nature, and tend to wear off quickly.

Aside from these comments, which are specific to the European process on flood risk management, there are also some general recommendations that can be made regarding the use of economic appraisal tools in the Member States:

- While this study was not intended to provide a comprehensive overview of all 25 EU Member States, the literature review revealed considerable differences regarding current role of economics in the process of selecting and implementing flood management. In some cases – such as the Netherlands, the UK and partly in Germany – CBA is a widely used tool in designing flood management strategies, at least on the local level and for designing structural measures. These countries have a fairly long tradition in the economic appraisal of flood management, which means that considerable skills and experience exists in terms of methods and approaches used. In the UK, the use of CBA is strongly institutionalised, through the requirement that central government funding is made conditional on a sufficiently high benefit-cost ratio. In other parts of Europe, the application of economic methods to the design and implementation of flood management policies appears to be much less common (e.g. in the case of the Spanish Jucar basin, where economic aspects are at least not discussed explicitly [FLM41]). In France, it appears that policy making has gone “beyond” Cost-Benefit Analysis: while CBAs were used more widely for policy support in

³³ An example of such “bounded decision making”, whereby the scope of economic analysis is limited by political decisions taken a priori, is given by the Dutch Government’s decision that no building should take place in marshes whatsoever, no matter what the outcome of a cost-benefit analysis would suggest. (Wind 1999) [FLD26]

the past, in recent years the focus appears to be shifting towards the use of Multi-Criteria Analysis and other assessment tools.

- Whether or not the current use of economic appraisal tools in the different Member States can be considered as sufficient cannot be determined once and for all. To what degree economic rationale is applied in flood management is largely determined by the political culture and tradition in a country, and by the availability of sufficient skills and knowledge both in the political and the scientific realm.
- The question whether the current use of economic appraisal tools is sufficient is also, to some degree, a normative issue: economic appraisal tools are primarily concerned with the economic efficiency of the result obtained. Although a wide understanding of economic efficiency would also include some environmental and social impacts, economic appraisal tools are nonetheless of limited value for reflecting other criteria such as impacts on equity / distribution of wealth, preservation of historical and natural values, avoidance of personal stress, or the degree of solidarity in flood risk management [FLD26]. Such impacts are problematic to include in economic appraisal tools, as they would need to be monetised in order to be included. However, expressing solidarity or avoided anxiety in monetary terms can at best be a proxy. For policy decisions where such values are of importance, the use of other assessment tools may be necessary, with Multi-Criteria Analysis as the most established alternative mechanism.
- Apart from the cases where economic impacts were not considered at all, this study did not find many indications that the current role of economic approaches in flood risk management is inefficient in the sense of producing results that are obviously wrong. However, it was observed in different instances that the results of a cost-benefit analysis are overruled explicitly by other considerations. This is expressed e.g. in the Dutch categorical decision not to allow development in marshes and floodplains, irrespective of cost-benefit considerations, or in the case of Cologne, where a proposed set of measures was implemented in its entirety, despite the fact that for some measures the costs outweighed the estimated benefits.³⁴ Such cases do seem to suggest that the use of a CBA is somewhat redundant, and that the results of an analysis are swept away by political pressures in the wake of a flooding event. It also serves as an indication that in the political practice, the benefit-cost ratio is but one decision criterion among others.
- One factor that does give cause to concern, however, is the widespread neglect of intangible benefits and of environmentally beneficial side-effects in many CBAs, or the failure to include non-structural measures altogether (see e.g. the case of the Lippe [FLM79]). If one assumes that environmental benefits (such as the value of a floodplain as a habitat) are mainly associated with non-structural measures, this introduces a bias in favour of structural measures. As Brouwer and Ek (2004, [FLE23]) demonstrate for the case of the Rhine delta, whether or not such effects are included can tilt the balance of judgement on the economic desirability of a project. One main obstacle to the systematical inclusion of intangible benefits and environmental benefits in flood-related CBAs is that these benefits need to be valued in monetary terms. Depending on how they are specified, conducting such valuation studies can be expensive and time-consuming. In addition, monetary valuation of certain impacts may be confronted with moral objections, most notably in the case of human lives. However, the cost and time requirements for valuation studies can be reduced significantly if valuation results can be transferred from previous studies conducted elsewhere. This is particularly attractive in the case of the ecosystem services provided by wetlands in floodplains (e.g. nutrient cycling, habitat, provision of biomass etc.), as wetlands are among the best-researched biomes.³⁵ However, it needs to be assessed on a case-by-case basis whether the conditions for such a benefits transfer are given, i.e. whether the studied site is sufficiently similar to other sites where valuation studies have previously been conducted. The concept of benefits transfer is discussed in greater detail in the Box below.

³⁴ Personal communication with Mr. Reinhard Vogt, of the centre for flood protection of the city of Cologne. Mr. Vogt indicated that in one case, a measure was implemented although the calculated costs outweighed the benefits by a factor of 16:1.

³⁵ See e.g. R.Kerry Turner, Jeroen C.J.M. Van Den Bergh, Roy Brouwer (2004): *Managing Wetlands: An Ecological Economics Approach*. Edward Elgar

Box: Environmental benefits transfer as a substitute for primary valuation studies³⁶

Environmental benefits transfer is a technique whereby the results of previous environmental valuation studies are applied to new policy or decision-making contexts. In the literature, benefits transfer is commonly defined as the transposition of monetary environmental values estimated at one site (study site) to another site (policy site). The study site refers to the site where the original study took place, while the policy site is a new site where information is needed about the monetary value of similar benefits. A number of criteria have been identified in the literature for benefits transfer to result in reliable estimates:

- *sufficient good quality data*
- *similar populations of beneficiaries*
- *similar environmental goods and services*
- *similar sites where these goods and services are found*
- *similar market constructs*
- *similar market size (number of beneficiaries)*
- *similar number and quality of substitute sites where the environmental goods and services are found.*

The most important reason for using previous research results in new policy contexts is that it saves a lot of time and money. Applying previous research findings to similar decision situations is a very attractive alternative to expensive and time consuming original research to inform decision making. In practice, several approaches to benefits transfer can be distinguished, which differ in the degree of complexity, the data requirements and the reliability of the results. In practice, benefits transfer would normally use the unadjusted results from another study to predict the economic value of the benefits involved at the policy site. Ideally, the original study focuses on the same environmental goods or services, but was carried out at a different location or at a different point in time. A second approach is to use and average the unadjusted mean point estimates from more than one study, if available. More refined approaches would use the results of one or more valuation studies and transfer them by adjusting them to specific factors that are expected to have an influence on the valuation results, e.g. adjusting for differences in income levels between the different sites.

Thus, while benefit transfer provides a quick and cheap alternative to original valuation research, the results may be unreliable. The risk of obtaining misleading or even wrong results is largest if the circumstances and conditions in the new decision-making context are very different from the ones prevailing in the original research. As explained, the risk may be controlled and reduced by integrating more explaining variables into the transfer, however this also increases the data requirements and the complexity of the analysis.

- At the same time, despite all economic considerations, decisions on flood risk management are very much driven by events. In the aftermath of major floods, far-reaching decisions are often taken and implemented swiftly, apparently irrespective of cost-benefit considerations. This concerns not only investments in large-scale protection measures (e.g. dyke reinforcement and heightening), but also strategic re-orientations of flood management altogether. Dutch flood management policies actually provide examples for both these effects: in the wake of the 1995 Meuse floods, a strategy of reinforcing and increasing dykes was decided, including an emergency financial plan (Deltaplan) in order to ensure reinforcement of all protection measures within two years. Only a year later, the realisation that these measures proved overly costly led to a substantial revision of Dutch flood management policy towards an integrated flood management based on the ideal of “*space for rivers*” [FLD26, FLE23]. While this phenomenon was not investigated in-depth in this study, it can be alleged that not all such decisions would have been feasible in the absence of major flooding events.

³⁶ This box is based on: Brouwer, R. (forthcoming). Environmental benefits transfer: Testing the Empirical Evidence. Kluwer Academic Publishers.

Despite their limitations, economic appraisal tools are able to make a significant positive contribution to flood management, as they force decision makers to consider the costs and benefits of their actions and to aim for an efficient allocation of resources. One of their most criticised aspects, the need to monetise all impacts, is also one of their main strengths, as it allows the comparison of different measures beyond the local scale. Provided that consistent methodologies are used, it is possible to compare the benefit-cost ratio of measures in upstream and downstream areas, in order to define an approach that is efficient at the river basin scale. In this respect, economic appraisal of flood management can play an important role for the integration of flood management strategies, both within and between countries:

- Flood management policy is not only water policy. It is also related to other areas of environmental policy and to other policies, especially to land use policy. This linkage to other policy areas becomes even more important as concepts such as “living with rivers” or “giving space to rivers” give greater weight to such policies, and less to technical engineering measures. In order to fully assess the impacts of a flood management strategy, the assessment would also need to reflect impacts on other policy areas and their respective targets. In this context, special consideration has to be paid to the real estate market and to the system for recovering flood damages, both by insurance companies and by public actors.
- At the national level, most European countries have different regulations and responsibilities for flood risk management, including civil protection. Both issues are regulated by different laws (spatial planning, water, housing, environmental, civil, nature conservation, agriculture). Flood management is thus a crosscutting task that needs to deal with overlapping or even conflicting responsibilities. In this process, economic appraisal tools can play a supporting role in order to demonstrate the necessity of an integrated approach, to make trade-offs with other policy objectives more transparent, or to frame and structure the process by listing options along with their pros and cons.
- Different states have priorities for dealing with floods, a fact that is also reflected in their legal regulations. For example, following an overhaul of different legislative items in recent years, German regulations now tend to focus more on flood prevention measures, whereas regulations in Poland and the Czech Republic tend to focus more on the management of actual flooding events, including emergency responses [FLP28].³⁷ While economic appraisal tools cannot and should not eliminate such differences by prescribing a certain approach – the role and relevance of economic appraisal itself being defined through the national discourse – they can help to establish a common frame of reference and serve as a basis for discussions, e.g. by enabling a comparison of measures.

> **Research needs**

Floods are a natural phenomenon, but they are also a river management issue. Although the occurrence can be mitigated to some degree, floods cannot really be prevented, they can only be managed. To do this effectively, and to address the rising tide of public concern, a better understanding of floods is needed. Public participation, cost effectiveness, function evaluations, land use changes and political and planning issues are only some of the issues that can be mentioned. Answers to open questions related to these topics have even become more important due to the current shift of paradigms in flood management that has already taken place in some countries, and that other countries are in the process of experiencing. As traditional technical engineering approaches, such as dams and dikes, are reaching their limits, non-structural flood management measures, such as floodplain management, are gaining in importance. This coincides with a more holistic view of flooding that considers interactions throughout the river basin. There are several open questions arising from this study that should be considered in order to support policy makers with additional information for better policy making:

- Within the present study, only a literature-based survey of the state of the art in economic assessment of flood protection measures could be given. In order to gather more sufficient

³⁷ For a summary, see http://www.umweltbundesamt.de/wasser/veroeffentlich/bmu_umwelt/ikso.htm .

information, an in-depth study involving a set of comparative case studies should be established in order to investigate options how the current appraisal techniques (economic and otherwise) could be developed further, in order to support a river-basin wider co-ordination and the strategic planning of measures. Such a longer-term study could be established under the 7th Research Framework Programme under the cross-cutting activity “policy oriented research”. This would offer a good opportunity for a deeper investigation in close connection with local actors and policy makers at different decision levels.

- The lack of information and data, as well as the variation of data used in different studies, was recognised as one main obstacle limiting the further use of economic appraisal tools. The methodology of CBA is sufficiently developed and widely accepted, but its use is often constrained by a lack of data. Improving, coordinating and harmonising data collection, as well as the development of common reporting standards (e.g. for the calculation of damage) could enhance the comparability of results, both within (transboundary) river basins and between different river basins. Where a common standard for data gathering for flood management is established, it should be closely connected with, or even integrated into, existing requirements under the WFD.
- Besides these efforts to facilitate a greater role for economic appraisal tools in flood risk management, certain primary data gaps have been identified. These concern descriptions of the specific temporal and spatial structure of a flooding event, leading to a more dynamic analysis of the related damages. In the context of information measures, which were identified as potentially cost-effective measures, it would be of great benefit to have more information on how the behaviour of actors is influenced by the information provided to them before and during a flooding event. Also, there is a need to better understand the impact of non-structural measures and their effects on the impact of a given flooding event. Finally, basic estimates on the damage potential at the river basin scale and on the possible consequences of a flooding event (as they exist at the Rhine and Loire) are the starting point for any analysis of potential flood risk management strategies, but these do not exist in many European river basins at risk of flooding.
- One further finding of this project was that at the river basin scales, scenarios are either not used at all, or are only used in the rudimentary sense of comparing different run-offs, or by contrasting one path of action with one no-action scenario. More elaborated scenarios comparing different paths of action over an extended time frame, taking account of changing pressures etc., are rarely employed. In order to improve this situation, there is a need for methodologies that integrate economic issues with hydrological and ecological models, and that also incorporate social developments and their impact on flood risk management.
- A more elaborated treatment of scenarios would also allow to incorporate different types of benefits in a more coherent and complete way. Currently, the benefits of flood risk management measures are mainly assessed in terms of avoided damages. In a more long-term perspective, benefits should also include reductions in the damage potential, or at least limiting the growth of damage potential in flood-prone areas. To assess such effects, the use of scenarios would be necessary.
- Current methodologies for predicting floods and their impacts often do not offer a complete view of the threatened area since they cannot show spatial trends and are mainly model-based. In the post-crisis phase, quantification and characterisation of damaged areas is currently estimated using conventional data collection methods (population statistics, information in administrative documents, damage claims, etc.) and, in a few rare cases, by GIS (geo-information) analysis based on river network databases and simplified hydraulic models. Hydrological models, in general, tend to focus on specific issues only. There is a need to combine or couple models in order to provide decision makers with tools which address specific issues in real time.
- Integrated flood management should not be based on economic efficiency criteria alone, but also needs to reflect other objectives, especially environmental and social ones. CBAs, however, are predominantly oriented at economic efficiency. To give other objectives due consideration, supplementary approaches may be called for in cases where economic valuation

falls short of capturing the most relevant impacts. In this context, a promising option would appear to complement a CBA with aspects of an MCA (e.g. including non-monetised costs and benefits), or to further develop the CBA into an MCA (where monetary costs and benefits are included alongside all sorts of impacts, described in quantitative or qualitative form). Some knowledge of and experience with such approaches exists, e.g. in many French basins. On the European level, possible research initiatives would include the development of a manual, outlining different appraisal tools and their relation to flood management, and providing guidance on which approach to use in which context (e.g. driven by the complexity of the decision situation, the time available for the analysis, whether or not of significant social and environmental impacts are expected etc.). This could also include the identification and description of best-practice in the different Member States and basins.

- While it is acknowledged that not all impacts can be expressed in monetary terms, there is a point for more research on the economic valuation of environmentally beneficial side-effects of flood risk management measures and on the economic valuation of intangible damages, in order to arrive at a better and more consolidated data base. This would primarily concern the environmental effects that are most relevant for flood risk management measures, e.g. the ecosystem services provided by renaturated floodplains. In this context, a large body of primary data already exists, which provides a good starting point for the use of benefits transfer (i.e. transferring the results of one valuation study to another site). For the assessment of intangible damages (such as stress and anxiety of the affected population, or damage to cultural and natural heritage sites), much less economic data is available; such effects are therefore more easily dealt with in a qualitative way.
- In line with the objectives of the Water Framework Directive and the Aarhus Convention, stakeholders should have their say in the designation of flood risk management policies. Assessment methods that support the decision making on flood management should therefore facilitate public participation processes and incorporate their results. Cost-Benefit Analysis generally is not very supportive of public participation: while it is possible to elicit the valuation of environmental goods and services by interviewing the affected communities, the CBA itself is a fairly mechanistic approach, and tends to be perceived by policy makers and the public as a black box that prescribes a particular course of action. As noted above, one possible remedy is to complement the CBA with elements of an MCA, as this instrument is generally more conducive to involving stakeholders.
- A cost-benefit analysis can support the decision whether or not a certain measure is worth implementing at a certain cost, and it can help to define an efficient strategy. However, a CBA typically does not look at who bears the costs, and whether this distribution of costs is efficient. Extending a classical CBA or MCA, more research is needed in order to shed light on the question how the costs for flood management ought to be shared between government, private companies and the public, what level of risk the individual should cover and what risks need to be borne collectively, and how the costs for damage recovery should best be distributed (i.e. informing the trade-off between disaster relieve by governments vs. (compulsory) insurance against flooding events).